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BP Norway's FIELD OF THE FUTURE Implementation—A Case Study

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Abstract

BP's Norway Assets have been recognised as a leading practitioner in the implementation of innovative intelligent energy solutions, what BP calls FIELD OF THE FUTURE technology. The installation in 1999 of a fibre cable, linking BP Norway's headquarters in Stavanger with their offshore operated assets, has been instrumental in putting BP Norway in the vanguard of implementing this new technology and associated work flows. This paper will take a look back over the substantial achievements and benefits that have accrued through the implementation of these technologies and review the experience gained. It will also look forward to the plans BP Norway have for taking their achievements to an even higher level of performance by fully embracing innovative intelligent energy solution concepts in two major projects that come on line in 2010/11.

This paper will present case studies of the various enabling and novel technologies installed to date, how these have been integrated within the operating environment, and demonstrate the continuing delivery of value. Examples presented will include:

- implementation and progressive development of the Advanced Collaborative Environment (ACE) concept;
    - from an early pilot operations centre,
    - through the implementation of what is believed to be the World's first 24/7 Onshore Drilling Operations Centre.
    - to the current generation of operations and support ACE's.
- introduction and integration of FIELD OF THE FUTURE technology into the assets and how this continues to impact production and plant efficiency;
    - the first full scale life of field seismic array,
    - an innovative set of optimisation tools
    - remote integrated surveillance tools for real time remote monitoring of wells and plant.

These tools have not only enhanced collaboration locally, but also enabled effective remote support form BP's Technology Centre and from specialist consultants, resulting in sustained improvement in asset performance.

1. Introduction

The Norwegian Sector of the North Sea is a mature province where BP Norge, on behalf of its partners, operates two field centres; the Valhall hub, consisting of the Valhall and Hod fields (Partners: Hess Norge AS, Norske Shell AS and Total E&P Norge AS) and the Ula hub, consisting of the Ula field (partners: Svenska Petroleum Expl. AS and Dong Norge AS) and Tambar field (Partner Dong Norge AS). BP Norway's offices and support organisation are located in Stavanger on the south west coast of Norway. This paper will present a case study of the substantial changes that have taken place in the way these fields are operated, managed and maintained with the advent of wide bandwidth fibre optical based telecommunications infrastructure, commissioned in 1999. It will also briefly examine how the these lessons are now being incorporated and further enhanced in two major green field projects being conducted by BP Norge, namely, in the design of a new production and accommodation platform for the Valhall field and the new FPSO being developed for the Skarv field in mid Norway.

2. Location and Facilities

Some brief facts regarding the BP operated fields in Norway that have implemented FIELD OF THE FUTURE technologies, are outlined below.

2.1. Valhall Hub

Valhall and Hod are oil fields located in the southernmost part of the Norwegian Sector of the North Sea, some 220 Km off the South West Coast of Norway, See Fig 1. Valhall is located in 70 metres of water and started production in 1982 (Barkved et al, 2003)[1]. The field was originally developed with 3 bridge-linked platforms (Quarters, Drilling with 30 well slots, and Production/Compression platforms). Valhall has had an extraordinary development since start-up and will probably still be on stream until 2050. In 1990 the Hod field was commissioned using a well head platform tied back via a 13 Km pipeline to the Valhall field. Hod was the first remotely controlled platform in the Norwegian Sector. In 1996 a new bridge-linked well head platform was added to the Valhall complex with another 19 slots. In 2002 this was followed by a new bridge linked Water Injection platform with another 24 well slots and a state of the art drilling rig that could serve both the Injection and Wellhead Platforms. In 2002/3 two identical unmanned wellhead platforms each equipped with 16 slots and located about 6 km (one to the North and one to the South) from the existing Valhall Facilities were added. Power and remote control of the Flank Platforms are provided via a combined electrical and fibre cable. In 2010, the field will start production from a new field centre which is currently under construction.

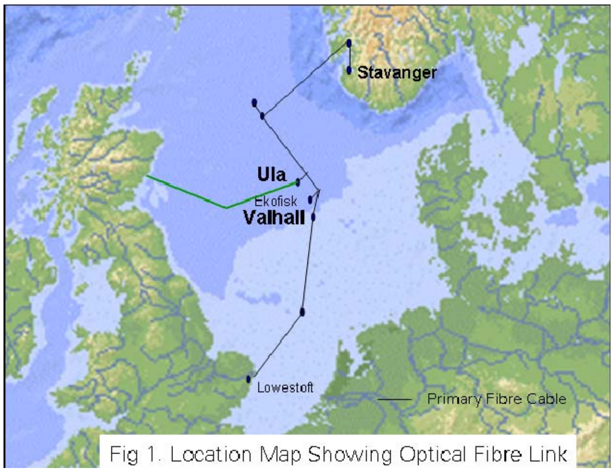

Fig 1. Location Map Showing Optical Fibre Link

Figure 1

2.2. Ula Hub

The Ula/Tambar oil fields lay to the North of the Valhall Hub and started production in 1986, ref fig 1. Ula consists of 3 bridge-linked platforms (Accommodation, Drilling and Production). In 2001 the Tambar field, which lies some 16 Km SE of Ula was commissioned as a remotely controlled wellhead platform tied back to Ula. Tambar gets its power from Ula, and control and telecommunications is via a fibre optic cable. Ula has undergone extensive upgrades to provide enhanced oil recovery, for example with the addition of water and gas injection capability. In 2007, a tie-back to the Ula field from the Blane field in the UK sector was commissioned. These changes have ensured the life of the field to well into the first quarter of this century and possibly beyond.

3. Historical Perspective for Telecommunications and Automation

One of the significant prerequisites for being able to make a step change in the way the Valhall and Ula fields are operated, has been the extensive upgrades that have taken place in the telecommunications and automation infrastructure since the 1980's. This section will briefly examine the principle technological changes that have taken place to enable Valhall and Ula to fully embrace the FIELD OF THE FUTURE Technologies.

3.1. Telecommunications and Digital Infrastructure

When the fields first started up, in the 1980's, both Valhall and Ula had limited telecommunications capacity. The primary means of communications to shore was via satellite communications. Each field initially had only 6 analogue telephone lines, two low speed telex lines and two 9,600 bit/sec digital links. The satellite links were expensive to operate and complex to maintain. The 0.5 second round trip delays and analogue echo cancelling technology made free flowing speech communications a challenge. Only the offshore radio and control rooms, together with senior platform management had direct dial access to the lines to shore. A limited number of data terminals were available offshore to access maintenance data held onshore. However, the satellite delay made their use slow and cumbersome. This resulted in limited collaboration and frequent misunderstandings, delays and errors being made.

By the early 1990's improvements in satellite technology started to change the way staff communicated. Digital techniques allowed for a greater numbers of higher quality telephone and data lines to be made available for the same price. Throughout the 90's there was a gradual improvement in collaboration between on-and offshore staff. PC's and e-mail gradually started to make inroads to offshore life, although the satellite delay still made their operation cumbersome. Loudspeaker telephones, which worked over satellite links, made possible the first "morning meetings" between groups of on-and offshore staff.

Although communications had improved in the 90's it had had relatively little effect on the organisational structure of the way fields were operated. It was a widely held view that without the introduction of reliable wide bandwidth low latency communications, via fibre optical cable, no significant progress could be made in changing this situation. In 1998, three operating companies in the southern area of the North Sea (at the time: BP, Amoco and Phillips), in a cooperative venture with a consortium of Scandinavian Telecommunication Companies, agreed to lay a fibre cable across the North Sea. The cable which connected the Ula, Ekofisk and Valhall fields to shore was laid in 1999 and gave access, in BP's case to two 155 Mbit/sec bandwidth links between the Ula and Valhall hubs and the shore based offices in Stavanger. See figure 1. for details of the route. This major improvement in telecommunications quality and capacity opened for a step-change in the way these fields were operated and put BP Norway's fields in the vanguard of development of what is today known in BP as FIELD OF THE FUTURE technology (in Norway this is more commonly known as Integrated Operations). (Lode, 2002)[2]

3.2. Automation and Control Technology

Valhall and Ula both started life with operating philosophies based on the use of local control outstations with only limited monitoring and control possible from the central control room. In 1994 Ula embarked on a major upgrade of their control and safety systems, designed to bring as much control as economically possible back to the central control room, located on the quarters platform. This involved replacing the ageing SCADA system and hardware based safety systems, with a modern programmable integrated distributed control and safety system. Around the same time Valhall saw the same opportunities and followed a similar path to Ula in upgrading their control and safety systems. Since the initial upgrades both fields have been subjected to a number of major modifications where the opportunity has presented itself to further improve the overall operability and grade of automation.

3.3. Lessons Learned

The Valhall and Ula teams are convinced that there is no substitute to low latency wide bandwidth communication either via fibre cable or microwave link if you are going to get the maximum out of FIELD OF THE FUTURE technologies. Satellite communications may appear the only alternative.

Without modern software controlled automation systems together with adequate field instrumentation much of what is described in this paper would not have been possible.

4. Towards the FIELD OF THE FUTURE

This section will review some of the major groups of FIELD OF THE FUTURE technologies that have been implemented in BP Norway's Assets. It will show how the above mentioned improvements in the telecommunications digital infrastructure and automation have been fundamental in significantly changing the way the onshore and offshore teams now collaborate and support optimal operations and development of the fields.

4.1. The route to the Advanced Collaborative Environments (ACE)

In the first years after the fibre optical link was established a good deal of experimentation took place to find what opportunities existed to exploit the new telecommunications link and to determine if the expected reliability would be achieved. In this period two separate project groups were established, one from the Operations team known as "Operations Centre 2000" and a second from the Drilling community called "Team 2000". Both groups worked with establishing strategies and pilots to exploit the new wide bandwidth telecommunications technology. Although these groups worked independently of each other they met regularly to share views and experience.

4.1.1. The First Steps

The first step made in 1999 was to establish a near broadcast quality video conferencing facilities on each offshore platform and in the onshore offices. Since so much bandwidth was available on the fibre link, BP was not restricted to the typical relatively poor bandwidth used for onshore video conferences at the time. The choice of going immediately for the best available wide bandwidth video conference equipment, proved to be a significant success factor. The effect was seen immediately by the number of meetings that started to be conducted via the video conference facility. Besides improving regular meetings such as the "morning" and "weekly planning" meetings, important face to face meetings, where staff would have previously been flown in to shore, were now conducted via video conference. Management "Town Hall" meetings were broadcast live with two way link-ups with the offshore staff and the onshore auditorium. This proved to be a catalyst for developing what has now became known in BP as the Advanced Collaborative Environments concept. (Edwards et al, 2006) [3]

Once confidence was built in the fibre links stability and reliability it was possible to move the business applications servers, that had been installed offshore to overcome the satellite delay, to shore. This saved regular offshore visits for the digital business support team.

Other tests were conducted to provide onshore access to offshore data contained in drilling and control systems. For example, remote operator stations were set up for each of the fields, vibration and corrosion data monitoring systems were linked to shore. Also the Drilling teams started to experiment with remote data monitoring.

4.1.2. Operations Centre 2000

Operations Centre 2000 Project was established in late 1999, with a mandate to investigate how far it was possible to take the concept for remote monitoring, maintenance and even operation from onshore. This project involved management, unions and staff representatives from both on and offshore. It resulted in a plan of how to proceed in a step-wise fashion towards the eventual goal of achieving some degree of remote control.

One of the outcomes of the work done in this project was the establishment of a pilot onshore operations support centre, or "Virtual Business Support Centre" as it was then called (Hocking, 2001)[4]. The centre housed remote operator stations for all operated fields at the time (which included besides Valhall and Ula also the Gyda field that was later sold). However, it should be noted that the centre was not permanently manned and only used on an ad-hoc basis. The centre provided a useful facility to asses new technology, for example the first version of the Valhall facilities optimiser and the model based slug controller for the Hod to Valhall pipeline were both tested and commissioned entirely from the onshore centre, without anyone having to go offshore. New concepts, such as prototypes for wearable PC based video conference tools, which later became known as Visiwear, were tested from the centre. The first steps were also taken towards remote performance management by interfacing to offshore machinery monitoring and vibration data in the centre. A good example of an early success was that an onshore production engineer, working remotely in collaboration with the offshore staff, managed to identify and implement a change that delivered a 5% increase in production on one of the fields (Drinkwater, 2002)[5].

4.1.3. Drilling Team 2000

The BP Drilling Team also saw opportunities for using the real time data that the fibre cable made available to them and together with Baker Hughes INTEQ embarked on a pilot project known as Team 2000 to test out the concept.

Team 2000 represented a different way of working, i.e. new work processes, where IT and Telecommunication technology could be used to transfer large amount of data between offshore and onshore, -and vice versa, - and where the work distribution between onshore and offshore would be fundamentally changed because of it. The idea supported BP's vision where "The decisions are made by the right person, based on the right knowledge independent of time and place"

The objectives of the Team 2000 pilot were to test out the concept of remote support on two Valhall wells. In cooperation with Baker Hughes INTEQ (BHI) it was agreed that services with regard to Directional Drilling, Measurement Whilst Drilling, Surface Logging Systems and Drilling Fluids would be performed at the same level of

quality as with a traditional offshore based service, but where the offshore crew was reduced from 10 to 6. The driver for both BP and BHI was, however, related more to a long term objective, where both companies had identified that the Team 2000 concept offered the potential to increase service and quality level.
The Strategic objectives of the pilot were:

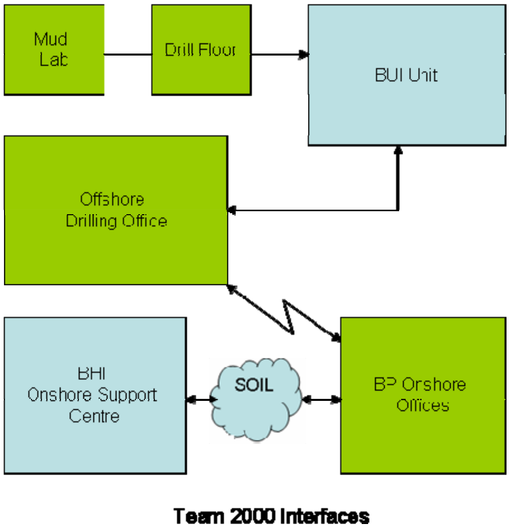

Figure 2

- Maintain good HSE results
- Increase Net Present Value through improved well positioning, made possible by fast data access and analysis
- Reduce client costs through improved quality of delivered services
- Reduce Baker Hughes INTEQ costs

The technical set-up for the Team 2000 project was more sophisticated than the Operations Support Centre described in Section 4.1.2 as can be seen from the Figure 1 below. It not only linked the offshore drilling rig with BP's offices but it more importantly linked to the pilot onshore operations support centre established at BHI offices. The link between BP's offices and BHI was established via the Secure Oil Information Link (SOIL)[6].

The results and conclusions from the pilot was that it was a success and proved that remote support was possible and that the transformation in working practices led directly to reduced operating costs, improved oil recovery and improved HSE performance. The Team 2000 Pilot was taken forward by BHI and is today know as the BEACON concept. Further details can be found in the referenced SPE paper (Wahlen et al, 2002)[7]. The work done in this pilot was used when the BP Drilling Onshore Operations Centre was developed.

4.1.4. Drilling Onshore Operation Centre (OOC)

The vision of the Drilling OOC was to "create an offshore virtual reality onshore, and let technology bring people together in a truly integrated team, to significantly improve Valhall drilling performance, optimise production and become a Great Operator". The aim was that through the use of the OOC, they would create a single, shared & interactive workplace and thereby achieve greater integration between the offshore and the onshore drilling effort.
The OOC was developed as an Onshore Operations Centre connected to the new Valhall Injection Platform Rig via the fibre optic cable to enable real time communication. The OOC was not intended to be a Visualisation Centre, but visualisation techniques are utilised (real-time data, large screens, videoconferencing, flexible video, rig radio and audio). However, the primary intent for the OOC was to get integration of onshore and offshore work processes. The OOC was designed to be an integral part of an enhanced team effort focussed on efficient well construction. The OOC from the outset has provided 24/7 round-the-clock support to the Valhall Injection Platform drilling operation. The importance of making informed, multidiscipline decisions continuously during the drilling of the well was a significant driver for why BP chose to do this.

A multi-discipline team was formed to provide the core team for the development of the OOC concept. Its members were drawn from operator and service providers, together with BP's own drilling, geology and digital business personnel.
The OOC project based their new organisation on lessons learned from other projects like Team 2000.

The aim of the OOC is to ensure that all drilling data normally available offshore will also be available in the OOC (pull on experts resources onshore). Therefore, positions or functions primarily concerned with data monitoring, processing and reporting can be located in the OOC. However, running equipment and physical interaction will still require positions to remain located on the rig e.g. mud logging.
Final crew composition on the rig and in the OOC is the result of a dialogue between BP and the actual service providers re-examining their work processes. Any changes were also subject to safety reviews.

Benefits

As the first of its kind it set the direction for the drilling industry. The benefits identified have been as follows:

- Identified cost savings $3.1 M after 3 months operation
- World first remote operated cement job.
- Moved approximately 10 positions from offshore to onshore
- Enabled 2 drilling operations on Valhall w/limited bed space.
- More and better involvement in planning and execution of wells.
- Continuous daily savings from operating onshore vs. offshore.
    - Helicopter.
    - Offshore beds.
    - Ad- hoc service personnel.
    - Shorter mob/demob time.

The success of the OOC was that BP have created a communication arena where multidiscipline resources can, and do, communicate based on a common and current situational awareness. For example, reservoir geologists work in the OOC while conducting geosteering in horizontal sections. They share interactive visual models in real time to communicate both the reservoir team's needs and help to resolve unexpected results.

The OOC has assured that the wider team's competence is involved in deciding on complex operational challenges; a prerequisite of delivering wells in one of the most challenging locations in the world: the Valhall Crest.

The OOC concept has stimulated behavioural changes and broken down the borders between on- and offshore as well as between the different disciplines (Tyberø et al, 2005)[10].

4.1.5. Valhall stimulation room

In order to achieve adequate production rates from the low permeability chalk reservoir at Valhall field the wells are stimulated using a prop frac technique which is both very time consuming and very expensive. Prior to installation of the fibre cable stimulation engineers from both BP and the stimulations supply company would travel offshore to run the jobs. Typically a number of trips were made for each well and long trips and frequent travel made retaining skilled engineers difficult. In 1999 one of the first applications of the fibre was to bring all of the necessary data for making fracing decisions to shore, so the engineers from both BP and the suppliers could work onshore supported by their full teams with the following improvements:.

- Delivered: 5% (min) increased production
- Process improvements:
    - Step change in utilization of existing staff
    - Improved collaboration/integration with supplier, subsurface and other experienced well engineers
    - Improved tuning of critical frac fluid chemistry
    - Improved modelling and production matching
    - Reduced offshore trips and staffing

It is interesting to note that these radical improvements were obtained without any formal analysis of the work processes. The new way of working was so much better than the old way of doing things and only a single discipline was affected so there was no resistance to the changed work process.

4.1.6. The Integrated Operations Environment (IOE)

Resulting from the successful work done with the pilot support centre, a new project was started to take the concept further with the aim of providing a fully integrated operations environment. In 2003, a complete rebasing of BP's operations in Norway took place spearheaded by project known as "Great Operator for the Future". Under the umbrella of this project the follow-on from Operations Centre 2000 became known as the "Integrated Operations Environment" (IOE).

Improved collaboration between onshore and offshore was identified as an area with high potential for business improvement. The team was able to build on the work already done in the pilot operations support centre and the Drilling OOC. Human factors based design tools were used to ensure optimal Human Technology Organisational (HTO) integration. Employee input and buy-in was assured through face-to-face interviews and workshops involving both on-and offshore staff.

A key success factor was seen as the physical working environment which needed careful design to promote open information flow and behaviours that would lead to improved operational and production efficiency. An important aspect was to facilitate ease of co-operation between groups onshore and offshore. To gain improved transfer of experience and changes in work processes, it was seen as imperative that the main IOE rooms functioned as the normal working areas for staff and not just as a specially equipped meeting room to be used when required. This was one of the learnings that came out of the Operation Centre 2000 pilot. A lot of effort went into determining which work would most naturally be done in the onshore IOE, to support the different offshore functions. At the end of the select phase in 2003, two separate proposals were presented for Valhall and Ula hubs. With the high level of activity at the time, commissioning the new Valhall Drilling and Injection Platform and Flank Platforms, it was decided to move ahead the Ula field first. The Ula design was finalised using a combination of surveys and workshops. This work identified two main focus areas for the onshore IOE, firstly, integrated planning and maintenance support and secondly, production and wells optimisation.

The project team wanted to also provide similar IOE facilities offshore. However, the existing offshore layout on the Ula field proved sub-optimal. The team wanted to make an open plan office area for management and supervisory staff, however this proved impracticable to achieve. The final solutions provided video conference facilities in each of the supervisor's offices and extend the Production Supervisor's office to facilitate an extra office space for the production coordinator and a meeting area. The survey team identified that it would be advantageous to provide video conference facilities in the offshore central control room linked to the onshore production optimisation IOE area. There were challenges associated with introducing VC technology into the control environment and ensuring continued safe operations, but overcoming these challenges resulted in significant improvement in collaboration between offshore operators and onshore engineers.

The final IOE onshore consisted of two co-located rooms linked by high quality video conference facilities with offshore offices:

The main onshore IOE room houses front line discipline support engineers, field planning and maintenance functions together with an offshore operations coordinator (who is an offshore employee who rotates shifts between on and offshore). The room is provided with direct video links to the Offshore Production and Maintenance Team leaders. Large video/data screens are used to enhance communication with offshore, who have similar equipment in the production and maintenance offices offshore. Access is provided via data to desktop tools to offshore plant data.

The Production Optimisation Room (POR) has the primary function to promote collaboration with the offshore Central Control Room in order to optimize production. This room is co-located with the main IOE room and is the permanent working place for the onshore Process Engineer, but with sufficient space to allow other staff such as: wells, automation and metering and allocations engineers to use the room on a part time basis. The room is equipped with video conference facilities for communicating with the Ula CCR, Production Supervisor, and the remote support facilities at BP's UK engineering base at Sunbury. The POR is equipped with operator stations to allow the engineers to see the same information as the offshore Central Control Room. Remote monitoring of the advanced control and fiscal metering systems, together with access to all the other data through extensive data to desktop (D2D) applications are also provided. (Hocking, 2004)[9]

Figure 3 Ula IOE

The project team recommended that the IOE should ideally be manned 7 days a week, but this proved impractical due to the high cost of providing shift staff to cover such an operation. The IOE is therefore manned during normal office hours only.

The IOE has been in operations for over three and a half years and significant benefits have been achieved. A much tighter integration between offshore and land has given substantial improvements in work planning and execution. Fast and effective decisions are now made based on the right information being available to all parties. Considerable benefits in terms of production up time and throughput have been achieved; Ula has one of the highest plant availabilities in BP, despite having only a single production train. Experience transfer from the work done on the Ula IOE has fed into the global FIELD OF THE

FUTURE initiative to develop what has now become known in BP as Advanced Collaborative Environments (ACE) (Edwards et al, 2006)[3]

In 2005, a new form of remote collaboration was established between the BP's FIELD OF THE FUTURE remote support ACE in the UK and the Ula POR. This has proved a great success where experts in the UK have been able to provided advice and solutions relating to barrel chasing opportunities that have given significant improvements. For example, remote cooperation between BP's UK engineering specialists and the vendor to tune the Ula slug controller model gave an extra 1 mbd in improved oil production.

In 2005, Valhall Re-development Project took over responsibility for delivering the IOE for Valhall as part of their project in 2010. However, the Operations Team for the existing facilities had seen so many benefits accrue from the Ula IOE they also wanted to establish a pilot IOE right away, rather than wait till 2010. Assisted by the BP Global ACE design team they created a production support IOE room, as an ad-hoc facility where engineers, whose normal offices were just outside the room, could go in to use the facilities such as the Valhall Operator Stations, Control System Maintenance Terminals, Valhall Optimiser and Machinery Monitoring Facilities. The Valhall Operator Training Simulator was also placed in a room besides the operations support room. Two new meeting rooms were also provided. Both the onshore IOE and meeting rooms together with the Valhall Control Room meeting room and the General Office meeting rooms offshore were also equipped with the latest audio visual equipment including high definition video conference equipment and smart white boards. This has proved to be a successful starting point for the Valhall team, so-much-so that the Re-development project pre-operations team are now proposing building a pilot IOE in the near future to gain experience for well and production optimization facility (Stornes, 2007)[24].

4.2. Reservoir and Well Surveillance

4.2.1. Valhall Life of Field Seismic (LoFS)

In 2003 120 km of three component seismic cables were trenched into the seabed around Valhall field initiating a new era of reservoir management in the field (Barkved et al, 2003)[11]. Eight Life of Field Seismic (LoFS) surveys have been acquired to date with repeat intervals as short as 3 months and currently two surveys are usually acquired per year. The data has been integrated into a wide range of reservoir management activities including new well delivery, well interventions, well perforation performance, waterflood monitoring, and has been integrated with the reservoir model. Figure 4 shows the seismic 4D images along between the baseline and subsequent monitor surveys show how the depletion develops around a single well. The time-shift maps relate to stress state changes outside the reservoir as the reservoir compacts during depletion (Barkved et al, 2005)[12].

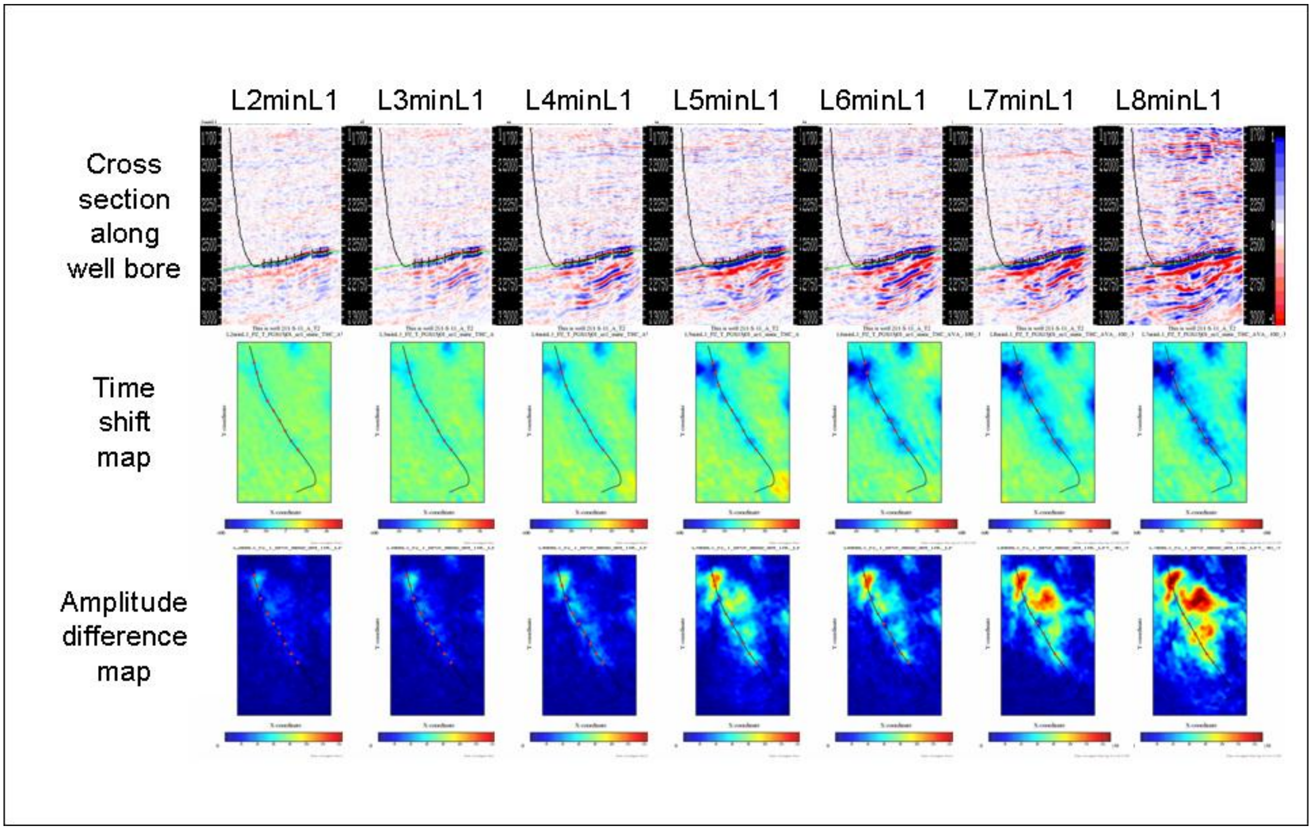

Figure 4

In order to take advantage of the frequent acquisitions an automatic processing workflow has been developed that has resulted in final data being delivered in as little as 5 days. Attributes, analysis and seismic "PLT's" generated from 422 automatically derived seismic volumes are loaded to a webpage for easy access by all team members (van Gestal et al, 2007) [13].

The earliest application of the LoFS data was for new well delivery where the 4D images and an improved static image under the shallow gas cloud (in the central part of the field) has been important for most of the wells drilled since 2004. In the most central part of the gas affected area the converted waves, seismic waves being converted from pressure waves to shear waves at the reflector, is critical to placement of new wells. In spite of the improved imaging in these areas, there is still significant untapped potential in the converted wave imaging which requires further efforts. In areas outside of the shallow gas the production/injection induced 4D seismic response is impressive and details are seen at levels down to individual well perforations (Barkved et al, 2005)[14]. The predicted production effects from seismic have been checked by PLT's in four wells with overall good the agreement. For base management the data has been used to directly support the interventions in two wells and used for quality assurance and risk mitigations in additional wells.

In reservoir management the current focus has been on integration of seismic observations into the reservoir model and direct determination of pressure, saturation and permeability. The data have been used to help select between different reservoir model options and even played a significant role in the gas oil relative permeabilities that are used in the current reservoir model (Barkved et al, 2005)[15], (Kielstadli et al, 2005)[16]. Recent surveys integrated with a variety of other data have also been used to monitor the waterflood direction and performance. The data are also the basis of an ongoing structural re-definition that will be critical for future infill drilling opportunities.

In the future we will continue to increase our quantitative uses of the data and continue improving cross discipline integration and the converted wave imaging.. Likewise, we would also like to expand the array so that it covers the entire field. For further information see paper (Watts, 2006)[17].

4.2.2. Integrated Surveillance Information System (ISIS)

ISIS is BP's FIELD OF THE FUTURE tool that takes well data from the point of acquisition through to decision makers, enabling them to make production decisions and implement relevant actions (Foot et al, 2006)[18].
The latest productised version of ISIS was commissioned recently for the Valhall Field, although they had been using an earlier version to provide basic visualisation of well data since 2005. Ula was also getting improved well data by just using the basic Data to Desktop visualisation tools mentioned in section 4.3.1, as they currently have limited well instrumentation.
The new Valhall ISIS system is being implemented and set up to work on all the current operating wells on Valhall. Alerts have been implemented to warn of slugging conditions, which, with so many wells is seen as a great advantage to the duty well engineers. A Value Realisation Process is currently being conducted on Valhall to embed the new technology in the working processes of the Asset. It is believed that ISIS will make an important contribution to the pilot Valhall IOE centre for well and production optimisation, ref Section 4.1.6.

4.3. Remote Performance Monitoring

4.3.1. Data to Desktop

Although some data was available onshore prior to installation of the fibre cable, it was limited and cumbersome to work with and specialized software applications were needed to access it. As mentioned in Section 4.1, one of the first things done after the fibre cable was installed was to implement operator stations onshore for each of the fields. This enabled onshore staff to see exactly the same graphics and data as the offshore control room staff. Only a limited number of staff had access to these stations, however, those who did found them invaluable for monitoring, optimizing and faultfinding on process plant and wells.
These limited facilities gave a tremendous boost to collaboration between the offshore and onshore staff and it was clear that getting real time data to users desktop PC's would add even further value. Therefore, in 2002, work embarked on providing a master onshore data historian infrastructure. Initial access to the data was via thin client web browser software, which enabled users to plot and transfer data to spread sheets. In 2004 a new more sophisticated web browser tool for accessing data was installed. This provided improved visualisation of data to all users. It also enabled BP's engineering remote support centres and external partners to access the data if required. Duty engineers were very pleased with being able to log in remotely and help the offshore staff with any issue that occurred without having to drive in to the office. (Hocking 2007)[19]
In addition to basic visualisation, the fields are making use of BP's own FIELD OF THE FUTURE Data to Desktop (D2D) applications for, for example, equipment run time tracking, alarm management and valve monitoring.
Some of the important lessons learned here have been that providing secure access to fast updated data, from offshore sensors, delivered to onshore users in near real time, is not a trivial task and requires careful attention to detail, especially in the architecture adopted if you are not going to obtain good reliable results. Having user friendly web based tools that allow the users flexibility to either use standard pre-built templates or make their own, is seen as an important success factor.

4.3.2. Equipment Monitoring

At about the same time the fibre cable was installed; extensive upgrades were taking place on the Valhall turbine control and monitoring systems. With the advent of the better communications it was realized that it was possible for the data in these system to be extended to the onshore engineers too. This proved very useful, especially for BP's third party condition monitoring contractor. However, travelling to BP's offices when they wanted to get data proved impractical. This was resolved by making use of SOIL[6] to link the data from the new machinery monitoring system to the contractor's office. With the introduction of the data historians and web browser tools it has also enabled BP's turbine suppliers and corrosion monitoring contractors to remotely monitor relevant data whenever needed. BP's condition based monitoring contractor now reckons to be able to proactively detect up to 85% of potential failure on machines. This has been so successful that Ula and Valhall are constantly in the top placing in the league table for gas turbine availability amongst BP's North Sea assets. (Hocking, 2007)[19], (Fornè, 2007) [20]

4.3.3. Wireless based technology

BP Norge has also been involved in testing a number of wireless technologies to improve operational efficiency. Early tests with a prototype of a portable, wireless based, flame proof, video conference equipment has shown that this technology had the potential to vastly improve offshore-onshore collaboration (Hocking, 2002)[8]. Using this equipment onshore engineers were able to get a much clearer picture of technical issues, enabling rapid resolution of problems. This technology was seen as being so important to the Ula IOE's success that approval was given to include installing a permanent wireless infrastructure offshore. The Valhall re-development Project is now installing similar wireless networks for use with their brown field hook-up work. Both the new Valhall Field centre and Skarv fields will have wireless networks installed.

One of the challenges with wireless technology, in an offshore environment, is ensuring that adequate coverage is achieved. BP has found the effort to be worthwhile as having a wireless network opens up opportunities to use other wireless based tools to improve productivity. For example, handheld terminals for improving the speed and efficiency of the permit to work system, and tools to track maintenance work orders and shutdown execution progress. All of these are now in the prototype testing phase on Ula and Valhall.

4.4. Advanced Control and Optimisation

4.4.1. Ula Advanced Control:

Just before the fibre cable was installed in 1999, the BP Ula field became, as far as we know, the first platform in the world to introduce advanced multivariable predictive control (MPC) of their offshore production process. Although MPC was a well-established technology in BP's downstream business, the application to the upstream operation was a completely novel approach. Advanced MPC utilises powerful mathematical models of process dynamics to predict future process behaviour and produce appropriate control responses, making it possible to operate nearer to the operational limits and thereby improving production efficiency. MPC's capability of handling many variables simultaneously enables it to consistently perform tasks beyond the capability of the human operator.

The use of this technology led to a 2% increase in Ula's production and a reduction in CO2 tax (Hocking, 2004) [21]. However, the cost involved of flying specialist out to the field to modify or add other models proved a hindrance to getting even more value out of the MPC. With the advent of the fibre link and the IOE, together with secure links to the vendor, it became possible to quickly make changes to the model to reflect the changing production profiles.
Other advanced control models have been introduced to both Ula and Valhall, for example, to control slugging flow from wells. It has been possible to not only remotely monitor these from BP's Norway offices but also to involve BP's specialists in the UK to help tune the models.

4.4.2. Valhall Production Optimisation

The Valhall asset started experimenting with Optimisation technology in 2001, as part of the Operations Centre 2000 initiative. It was believed that down stream optimiser technology could be readily ported to the upstream, especially since real time data was now available from Valhall. In 2002, an on line advisory optimiser was built to optimise both production and reduce CO_2 emissions. Having the fibre telecoms links proved to be a great advantage as it was possible to do all the design and commissioning work remotely. This work showed that considerable production benefits were possible from consistent application of the model recommendations. The initial experiment did not lead directly to sustained usage and within a few months the optimiser was only being used for "what if" studies. In 2004 in cooperation with the FIELD OF THE FUTURE Optimisation Team and Valhall Asset engineers, it was decided to make a new attempt at getting full value from the tool. The project was split in to two areas: The first, involved technical work to update and improve the fidelity of the model and build trust in its results and the second, involved gaining a good understanding of the business processes and work flows involved to sustain the value generated by the optimiser (Stenhouse, 2006) [22].

The culmination of the technical work in 2005 showed that lack of important process measurements together with significant process variability meant that simply adopting downstream technology did not produce operational advice that was easy to use and interpret. The business process work also showed the importance of fully integrating the work flows associated with optimisation in to the Asset (Stenhouse, 2008)[23]. The project team went on to develope a prototype workflow that has proved capable of delivering material benefits to the Valhall Asset The new model brings together asset well, process and production engineers in a collaborative cross disciplinary workflow underpinned by the on-line optimiser. The output of the workflow is the best current operational strategy for the plant on a daily-weekly timeframe. This strategy can be enforced on the plant via operator guidelines, updated daily. In 2006 implementing these workflows on Valhall delivered in excess of 2 % production improvement, together with additional revenues of $3.5 million/annum from increased NGL recovery.

5. The future Valhall Field Centre and Skarv

The benefits that have been articulated above have all come from brown field sites; however, BP Norway has two major projects under development, namely, the Valhall Re-Development Project and the Skarv field development project.

Due to subsidence of the original Valhall Platforms built over 25 years ago and with a long life expectancy for the field beyond 2040, a new field centre is being developed for Valhall to be commissioned in 2010. The new centre will house both the processing facilities and a new accommodation unit. The intent is to power the Valhall field from shore via a high voltage d.c. cable. The power cable will also have an additional set of dedicated optical fibres. These will provide Valhall with two totally independent telecommunications routes providing such reliable communications that the project has decided to provision the field with the capability of being remotely controlled from shore. This has presented a unique opportunity to adopt FIELD OF THE FUTURE technology. The new offshore office area has been designed with collaborative working with the onshore IOE's in mind. The project will deliver and onshore control room for Valhall co-located with ACE's for wells, production support and integrated field planning. The field will be equipped with FIELD OF THE FUTURE remote monitoring features together with advanced control, optimization and wireless facilities to facilitate optimal operation and proactive maintenance and support from shore (Stornes, 2007) [24].

Skarv is a new green field development in the mid Norway area. It will involve building what is believed to be the worlds largest Gas Condensate FPSO's. Skarv will also be provided with access to a fibre optic based telecommunications infrastructure. As with Valhall the FIELD OF THE FUTURE teams have been working closely with the project to ensure similar levels of remote support and optimization.

6. Conclusions

BP Norway has pioneered many aspects of FIELD OF THE FUTURE technologies, with the following notable achievements:

- In 2000, piloting the first Operation and Drilling support centres, based on real time data from offshore, immediately showed tangible results, for example, a 5% improvement in production on one of the fields monitored from the centre.
- Implementing onshore real time data monitoring and improved audio visual communications with the fracing vessel delivered a 5% (min) in increased production.
- The Valhall Drilling Onshore Operations Centre (OOC) was the first of its kind in Norway and delivered cost savings of $3.1 M in the first 3 months of operation.
- The Integrated Operations Environment (IOE) for the Ula field contributed to improved work planning (10% improvement in planned work in first few months of operation) and numerous examples of production improvements.
- Data from the world's first full scale Life of Field Seismic (LoFS) installation on the Valhall field has been integrated into a wide range of reservoir management activities including new well delivery, well interventions, well perforation performance, waterflood monitoring, and has been integrated with the reservoir model.
- Making high quality real time well information available onshore through improved data visualisation tools has revolutionized the way well operations engineers can support the offshore staff. This has lead to numerous examples of improved well surveillance and productivity.
- Real time production, machinery, corrosion and erosion data made available to both BP staff in Norway, specialists at BP's engineering centre and specialist contractors has lead to fast and effective diagnosis of production and maintenance issues, which has contributed to delivering some of the best plant availability in BP.
- Successful pilot testing of wireless tools has resulted in installation of full coverage systems on existing and new installations to support new productivity and information sharing tools.

- Advanced control technology has been successfully deployed on both Ula and Valhall with significant impact on production; for example 2% improvement on the Ula field and improved slugging control on both Ula and Valhall.
- The use of model-based optimisation tools have been successfully pioneered on Valhall and have led to greater than 2% production improvement.
- New Norway projects (Valhall Re-development and Skarv) will have all the necessary instrumentation and applications necessary for them to fully utilise FIELD OF THE FUTURE technology.

Key lessons learned through these achievements include:

- The availability of wide bandwidth low latency communications is a key enabler for making optimal use of intelligent energy solutions and to achieving the ambitions to adopt FIELD OF THE FUTURE technology solutions.
- Whilst technology can be deployed relatively quickly, organizations tend take a longer time to adjust and people can take even longer coming to terms with the changes. Therefore, involvement of management and staff at all levels in the business transformation processes are vital to the success of implementing FIELD OF THE FUTURE technology.
- Change management needs to be fit for purpose. In general, the greater the number of disciplines involved in implementing a technology, or the further people are moved outside of their “comfort zone” in its use, the greater the emphasis will need to be in a persistent change management effort. Efforts led by champions internal to a particular asset have generally been the most successful.
- A key success factor has been the support and encouragement BP Norway’s management have given to the various FIELD OF THE FUTURE initiatives described in this paper, combined with the enthusiasm of the local staff for adoption of new technology where they can see it will benefit their assets and their own work environment.
- Sustainability is an important area to consider when working with FIELD OF THE FUTURE technology and in particular Advanced Collaborative Environments. Staff will move on and plans need to be in place to address the management of change for the new staff taking over; a few days handover is not enough. It can take months to get up to the same level of competence and comfort as those they are replacing.
- Measuring benefits from FIELD OF THE FUTURE technology is not a trivial task. Tight follow up of benefits normally occurs immediately after a new technology is commissioned. However, once the benefits are proven and it becomes “business as usual”, capturing ongoing benefits can prove difficult.

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