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Executive Summary

This master thesis provides the current application of remote support services in different levels. Although challenges and barriers exist, a trend of optimized integrated operation and maintenance using remote support services is changing the oil and gas industry development to higher efficiency and overall performance. The digital platform life will make our work easier, safer and challenging.

The maintenance strategy applied in the author's company is staying in the preventive maintenance period. A holistic approach in the predictive maintenance especially in condition monitoring, remote maintenance and collaborative maintenance is initiated which can bring new philosophy for the author's company development.

The remote support services using condition monitoring and online sensor data show major opportunities potential in the author's company. Making use of the ICT technology and learning from successful similar system, a remote support system fitting for COSL can be expected through continuous optimization on the existing system.

The recommendation put forward by this thesis is that further study are needed in business process optimization, technology integration and internet security.

During the master thesis composition, I attended the CIPPE international oil and gas equipment exhibition in Beijing and investigated many communication companies working for the smart oilfield development. The smart oilfield development mainly focuses on the collaborative maintenance and operation through condition monitoring and online sensor data. A questionnaire is also conducted for finding the current requirement of remote support services. Interviews with the equipment director and engineers of production optimization department of COSL also made me learn a lot and enriched my thesis contents. Special thanks should be given again to my thesis supervisor, Tore Markeset. He is always so easy-contacted and helpful in directing my thesis.

The master thesis composition is really a challenge because of my family and heavy company work load. So I change my original plan A to Plan B (shown in the following page) which is approved by my supervisor. There may have some unclear even wrong descriptions for the whole thesis because of limited time and less overall considerations, any readers can contact with me for clarifications or correct me.

Abstract

Based on advanced technology in condition monitoring and online sensor data, a new style of operation and maintenance management called remote operation and maintenance support services has been created to improve oil and gas E&P performance. This master thesis will look into how the remote support service is conducted including the concept, design, technology and management philosophies; the current implementation of remote support services in China, Norway and the rest of the world to breaking barriers and creating business values; Explore the performance in LCC, RAM (reliability and maintenance) level perspective and decision making through the using of condition monitoring and online sensor data; study the future development of remote support services and Integrated Operations (IO).

The author will study the state of art technology from literatures, company documents and consult to the professors and engineers. A study of remote support services in ABB, SKF and ConocoPhillips will be conducted as an evolution of integrated operations.

Further research is needed to face many challenges exist in the practical use of the remote support services through successfully breaking barriers to boundary-less organizations and developing management process and competent employees into the organization. The cultural change is difficult but fatal for the success of the system implementation.

The suggested remote operation and maintenance support strategy is not complete for CNOOC and COSL, but gives a conceptual and an academic idea for practical use.

Abstract in Chinese

在先进的状态监控和在线传感数据等技术发展的基础上，一种新型的远程支持维保操作系统在石油化工的开发生产过程中，在推进生产效率，提高设备可靠性等方面得到越来越多的应用。本论文将深入研究这种远程支持服务的概念，设计，技术和管理理念；目前该技术和管理理念在中国，挪威以及世界其他国家的现实应用情况分析，从而如何打破现有的执行障碍并创造新的价值；研究使用远程状态监控和在线传感数据的远程服务在全生命周期管理和可靠性维保，决策分析等方面的影响；远程支持服务和一体化操作在未来的发展趋势。

作者从文献，公司文件和咨询相关的教授学者和工程师等方面研究现在流行的新技术新应用。在案例分析中，分析了ABB，SKF，康菲等公司的远程支持服务和一体化作业。本文的重点不在详细的技术研究，只是这种集成化的理念如何在提高设备的利用率，可靠性和综合效率方面发挥作用的探讨。

在这种远程支持服务在实用的过程中会遇到各种挑战，接下来的研究仍然需要关注如何打破这些障碍实现无界限的组织模式和管理模式，并且让有能力的人员加入到组织中使得远程支持服务运转顺畅。公司文化的改变很困难但对这种远程支持服务的实施是最为关键的。

所建议的这种远程操作和维保策略在中海油和中海油服实际应用中是不完善的，但为以后可能的实际应用提供一种概念上和学术上的理念。

Preface

Since commencing my studies at the university of Stavanger in 2012, I have learned a lot about the remote support services using condition monitoring and online sensor. This technology and organizational management is weak in China, so I try to learn and explore more through literatures in the library, professors' lectures and company visit in ConocoPhillips and SKF. The remote support services can greatly increase the cost-efficiency, reduce the Life Cycle Cost from the long time perspective, reduce the exposure time in hazardous area and enhance QHSE performance.

During my thesis writing, I faced many difficulties to find relevant data for the detail technology of the remote support services, also for the financial analysis data. So I focus mainly on the qualitative analysis for the possibilities of application in COSL and CNOOC. Some of the data I used is not the real data but it is can be reasonable because the data are divided by the same rate. Because of this, the master thesis can be non-confidential.

Acknowledgement

I would like to thank my department manager in COSL, for his good consideration in balancing our work and master thesis writing. He told me that the master thesis writing is the top priority in this half year and he would spare no efforts to help in data collection and suggestions.

I would thank my faculty supervisor at University of Stavanger, Professor Tore Markeset, who gave me valuable and constructive feedback on my ideas and helped me define the scope of thesis. Without his constructive feedback and patient instructions, the thesis would not be completed on time. Especially the work is completed in China, which make it more difficult. His fight to china and valuable advice and guidance are really appreciated.

List of abbreviations

CCR: Center Control Room
CMMS: Computerized Material Management System
CNOOC: China National Offshore Oil Company
COPC: ConocoPhillips of China
COSL: China Oilfield Services Limited Company
DCS: Distributed Control System
DCWR: Drilling Completion and Workover Rig
EOT: Enhanced Organizational Teamwork
ERP: Enterprise Resources Planning
FAF: Fail and Fix
IAEA: International Atomic Agency
ICT: Information & Communication Technology
IO: Integrated Operation
IPO: Integrated Production Operations
KPI: Key Performance Indicator
LCC: Life Circle Cost
MCC: Motor Control Cabin
NPV: Net Present Value
OEM: Original Equipment Manufacturer
OPEX: Operational Expense
PAP: Predict and Prevent
PLC: Programmable Logic Control
POB: Position of Bed
QHSE: Quality, Health, Safety and Environment
RAM: Reliability and Maintenance
RCFA: Root Cause Failure Analysis
SCADA: Supervisory Control and Data Acquisition
SPIR: Spare Parts Inventory Record
VFD: Variable Frequency Drive
VPN: Virtual Private Network

Contents

Executive Summary.....	1
Abstract.....	2
Abstract in Chinese.....	3
Preface.....	4
Acknowledgement.....	5
List of abbreviations.....	6
1 Introduction.....	9
1.1 Problem formulation.....	11
1.2 Main objectives and sub-objectives.....	11
1.3 Methodology.....	12
1.4 Project activities.....	12
1.5 Research approach.....	12
1.6 Delimitation.....	13
2 Process of remote maintenance support services comprising with traditional type..	14
2.1 Traditional offshore support services.....	16
2.1.1 Types of support services.....	16
2.1.2 An example of traditional onshore support services.....	16
2.2 Remote support services using condition monitoring and online sensors	17
2.2.1 Model of remote support services.....	17
2.2.2 Remote support services in offshore oilfield development.....	17
2.2.2.1 COSL's remote support services.....	18
2.2.2.2 SKF's solution.....	19
2.2.2.3 ABB's remote support Services.....	21
2.2.3 Outsourcing and subcontractors in the remote support services.....	22
2.3 Comparisons between conventional and remote support services.....	23
2.4 Conclusion.....	26
3 The components and process of the remote support service.....	29
3.1 Sensors and transducers.....	29
3.2 Intelligent watchdog agents.....	30
3.3 Industrial computer or DCS system.....	31
3.4 Internet connection.....	32
3.5 Wireless computer applications such as smart PDAs and Mobile devices	33
3.6 Data computing and information management.....	33
3.7 Integrated operation and maintenance support centers.....	34
3.8 Condition monitoring optimization.....	34
3.9 System safety including Access to data and drawings.....	37
3.10 E-training for the remote support system.....	37
3.11 Conclusion.....	38
4. Case study of current practices in CNOOC of remote support services technology	

39	
4.1	Current condition monitoring and remote support services in CNOOC39
4.1.1	XPR 300 System overview42
4.1.2	RH2000 system.....43
4.1.3	Condition monitoring for critical equipment on drilling platforms44
4.1.4	Condition monitoring system in PL19-3 oilfield.....45
4.2	Conclusion48
5.	The role of ICT in condition monitoring and online sensor data49
5.1	The impact of ICT technology49
5.2	How to reduce the negative impact of ICT50
5.3	Wireless technology in condition monitoring52
5.4	Conclusion53
6	Challenges and barriers for remote support services54
6.1	Key operational workflow management54
6.2	Decision making.....54
6.3	Information logistics55
6.4	Departmental and Technology integration55
6.5	The balanced development of human, organization and technology and the related safety56
6.6	Key equipment selection57
6.7	Conclusion58
7	Possibilities of remote support services using condition monitoring and online sensor in COSL.....59
7.1	Investigations in COSL.....59
7.2	The platform features.....61
7.3	Investment analysis for the remote condition monitoring system application.....61
7.4	Conclusions.....65
8	Development trend of technology and management in condition monitoring and online sensor data communication.....66
8.1	Application of remote support services in the manned platforms66
8.2	Application of remote support services in some small production oilfield. 67
8.3	The integration of equipment, business and process automation68
8.4	Conclusion68
9	Recommendations and further research.....70
	Reference list72
	Appendix A: Questionnaire for remote support services75
	Appendix-B Classification analysis of spare parts.....77

1 Introduction

Without well-maintained equipment, a plant cannot operate well with many downtimes and less equipment availability rate, even failure when lose competitiveness. The maintenance is becoming more and more complex with the diversified process and equipment. Swanson(2001) explains that there are three types of maintenance strategies: the reactive strategy (breakdown maintenance), the proactive maintenance(Preventive maintenance and predictive maintenance) and the aggressive strategy(TPM). Traditionally, many companies employed a reactive strategy for maintenance, “fixing machines only when they stopped working”(Holmberg et al., 2010). Recently, remote operation and maintenance support services is becoming increasingly popular with the development of advanced technology in condition monitoring, online sensors and the transmission & analysis of data using web based services and advanced information & communication technology (ICT). For example, simulation-based software, internal network, advanced sensors planted with output terminal for long distance transmission, etc. The remote support services mainly focus on the maintenance strategy, which is a preventive and predictive maintenance strategy associated with aggressive maintenance. The aggressive strategy, like total productive maintenance (TPM), focuses on actually improving the function and design of the production equipment(Holmberg et al., 2010).

In nowadays companies, the remote support services are making great progress to become more cost-efficient and effective although many challenges exit. These challenges include the end-to-end IT infrastructure such as website and field IT, the design of the work processes to be supported, and the business model for company implementation(Landgren et al., 2008). Although some progresses have been made over the past years, the initial investment is large and high requirement for the process; employees and management philosophy also make it difficult to be practical. All in all, a trend of integrated operations/ e-operations is winning great attention globally. Then different related parties can work on the same platforms offshore and onshore, domestic and international. This make it possible for remote support services without any limitations from geographical limitations. The Tommeliten field was in 1988 the first field development as a remote controlled satellite field connected to the Edda field(museum and Histos, 2005). The remote support services are also successfully applied in some advanced oil field such as ConocoPhillips Ekofisk platforms, Valhall of BP. In ConocoPhillips, there is an onshore support optimization center in the office and all the stakeholder work online to make decisions on some operation and maintenance problems. Most companies believe that making decisions in real time while leveraging

global resources and infrastructure will help to improve their field productivity while reducing costs(Landgren et al., 2008). However, for the risk management and KPI management, it is very difficult for the companies to verify if the remote support maintenance services are more beneficial than the traditional support.

In COSL, the condition monitoring can be realized and the daily operational parameters can be transmitted and viewed in offshore CCR (center control room) or MCC (motor control cabin). From the author's company interview and investigation, only some important videos and geographical and operation data can be transferred to onshore for condition monitoring and decision execution. There will be great economical potential for the remote support services in promoting the safety performance and equipment management level if a special-designed system can be made to balance different considerations.

China Oilfield Services Limited ("COSL") is the leading integrated oilfield services provider in the offshore china market. Facing the fierce competition in the market, increasing cost and resources should be put on the optimization of the operation and maintenance to make our work safe and cost-effective. Nowadays, the condition monitoring such as vibration, temperature, ultrasonic, oil debris are conducted offshore or the company send some contractors to offshore for inspections periodically in COSL. Facts in COSL proved that the condition monitoring and inspection are low efficiency and high-cost job. Only limited inspections find problems and need many human resources sometimes. For example, some contractors have to go offshore to implement the inspection work and need a few hours for inspection, but he has to take the helicopter or boat which needs two or more days for a round trip, the time lead would be longer for some bad weather or military supervisions. Furthermore, a lot of safety risks exist during the inspection. How about transferred all these data to onshore and analyzed by onshore experts for remote support? But it may not be possible or economical to do it as the considerations of initial cost, life circle cost, the reservoir output and life, etc.

Mobley(Mobley, 2002) stated that " A relatively slow deterioration before failure is detectable by condition monitoring. Continuous online monitoring, real time detection and quick action is much more important especially in some critical processes. Systems usually include acceptable boundary definition, sensors and transmitters, computer-based PLC and logic control terminals as diagram 1(eMaint, 2012). In COSL, the power management system is being applied to manage drilling diesel engine generators online. Firstly the acceptable boundaries should be defined for the diesel engines which include coolant temperature, winding temperature and power output etc. Then the sensor's output can be transmitted to electrical signal which can be received and analyzed by PLC, then automatically trigger a warning, email or generate a work order when a reading indicates that boundaries are exceeded. If the drilling process is so

critical and the generator can't be stopped, the emergency generator will start automatically in case of the catastrophic modes of failure.

1.1 Problem formulation

Based on the above background the following problem is formulated:

1. What are the advantages and disadvantages of remote support services and cost/benefits analysis through comparing with traditional support services?
2. How are remote support service conducted (including the concept, design, technology, and management philosophies, etc.)?
3. How the data are managed? How are data-related activities outsourced? What types of data are collected? How is data transferred and analyzed? How to present the data and to whom? How to act on results? What other data is needed? How to access related data (drawings, plant health data, etc.) that are needed for the analysis
4. How to make maintenance today contributes to the sustainable development without only focusing on the economic aspects? Safety, people, energy saving and environmental protection also should be paid great attention even lose some economical and production performances.

1.2 Main objectives and sub-objectives

Main objective: To develop a remote operation and maintenance support strategy to optimize the maintenance performance using advanced ICT technology.

Sub-objectives:

- 1) Explore the current application of the remote support services
- 2) Explore the application of condition monitoring and online sensor data in remote support services
- 3) Explore how LCC cost, and availability and the predictability may be improved using of condition monitoring and online sensor data
- 4) Case study to looking for possibilities for remote support services in COSL and CNOOC.

1.3 Methodology

- Establish state of the art in remote operation and maintenance support strategy to optimize the maintenance performance using advanced ICT technology with special emphasis on the petroleum industry.
- Identify industry practice in CNOOC and COSL

1.4 Project activities

- Perform a literature survey to the current application of remote support services, a comprehensive survey should be conducted through referring to the database, related company website, and site survey of COSL offshore drilling and production rigs.
- Optimization of the condition monitoring and online sensor data in remote support should be achieved through reading some technical and managerial books, stimulating some remote support models and consult to the professors and experienced engineers in the industry.
- Learn and explore the theory and practical use of condition monitoring and online sensor data through reading some reference books, discussion with colleges and classmates, and consult to the professors and engineers.

1.5 Research approach

- Perform a literature survey using library databases, books, company information and internet resources
- Perform interviews and group discussions with experts, including university professors
- Perform a site survey on COSL production and drilling rigs
- Perform interviews and data collection from contractors that develop new technology for remote support services
- Compare the process of remote support services with conventional type of support to offshore operations

1.6 Delimitation

The master thesis is limited by time and length because of my high load work, study and private life. The case study need much more data, only the key information is not enough to get the conclusion I have addressed. The platforms are different in age, reservoir size and other different features both in china and the rest of the world, so the remote support services using condition monitoring and online sensor data is not suitable for all the offshore platforms. The master thesis only gives an analysis for these services including e-maintenance and e-operation which will be optimized with the development of technology, culture and organization management change.

2 Process of remote maintenance support services comprising with traditional type

Equipment management mainly focus on the maintenance quality, condition monitoring and proactive maintenance to higher reliability. Higher reliability of industrial plants and machines means fewer risks, both personal and environmental, and better control, as well as energy conservation and lower expenses during the operating lifetime(Holmberg et al., 2010). The proactive maintenance include the spare parts stock setup, predictive maintenance, RCFA (root cause failure analysis) and preventive solutions for the root cause.

Traditionally, the condition monitoring is poor and weak with only personnel feelings or limited hand-held gauges. Different maintenance engineer can get different equipment condition status and make different decisions on the maintenance plan. All the information comes from the site maintenance engineers and the truth of information rely on the competence of the engineers. Both the quantity and quality of the information will not be true to the original during the personnel communication from 90%,80%,.....to 40%. All the people work on their own method without proper cooperation.

Based on this situation, the scheduled maintenance is used as one solution, stopping the equipment regularly for checking and service(Holmberg et al., 2010). Some run-to-fail situations also occurs with downtimes and “fire-fighting”. However, a survey by the author’s company(COSL) shows that only 2.24% of the preventive maintenance found some problems and created corrective maintenance work order. The reasons are as follows:

- The machine have no time window to be stopped for inspection
- The maintenance man thought it is ok without any monitoring due to laziness
- Competence make a big difference in maintenance.
- The scheduled maintenance is not well planned as the machine need not inspect so frequently.

However, the cost of preventive maintenance is considerable. Mobley(Mobley, 2002) stated that preventive maintenance done poorly can be worse than no maintenance at all.

Holmberg(2010) also stated that the scheduled maintenance's problem is that the equipment is stopped also in unnecessary cases and sometimes the stop and unnecessary service action may introduce new problems.

The remote maintenance support services is a condition-based maintenance successfully developed with Intra-Net, Extra-Net ,Inernet, new sensor systems and data processing and diagnosis systems. The remote support system combines with advantages of the condition-based maintenance. By integrating the actual failure data acquired from condition monitoring techniques with historical data, the current health condition and the remaining useful life of the equipment will be evaluated(Dagneu, 2012). It has many benefits:

- The maintenance workflow are optimized to higher efficiency and lower cost.
- The downtime can be reduced
- Optimized stock level
- The on-site repair team can be reduced and reduce the hazard exposition.
- Better planning of repair, the repair can be in a easy way, not “fire fighting”

The popular e-maintenance solutions typically offer answers to the following questions:

- What: which equipment needs maintenance
- When: When is the maintenance needed
- Who: computerised maintenance management systems
- How: manuals, spare part availability(Holmberg et al., 2010).

With the development in the ICT technology in condition monitoring, the need-based maintenance or condition-based maintenance is realized with the cooperation of different departments working on the same platform.

Here we have a look at the comparisons of these two types of maintenance strategy in offshore oil and gas industry. From the comparison, the new and optimal solutions for assets management will show its benefits in an active way based on modern network information environment.

2.1 Traditional offshore maintenance support services

2.1.1 Types of traditional support services

Traditionally, some extra personnel are needed to work offshore to do some routine inspection or standby for maintenance, which make the POB (position of bed) is very tight in offshore rigs. Also, the cost of operation will increase because of the extra personnel's wages, accommodations and other costs. While the onshore support team sit in the office with many paper document and one computer.

With respect to maintenance, the diagnosis services are conducted by offshore site engineer when failures happens? The onshore engineer can get only limited information through e-mail and telephone. With the development of satellite communication, the remote support services through internet greatly improve the performance of remote support services, some video information can be transmitted to onshore and analyzed by onshore engineer. But the cooperation between different departments during drilling operations is quite weak.

2.1.2 An example of traditional onshore support services

Traditionally, the onshore support services team has to go offshore with inspection and diagnosis instruments to go offshore to record the data, then analysis the data and find the solutions or make the O&M plan. The conventional support services are showed in figure 2-1 using the engine generator failure as an example.

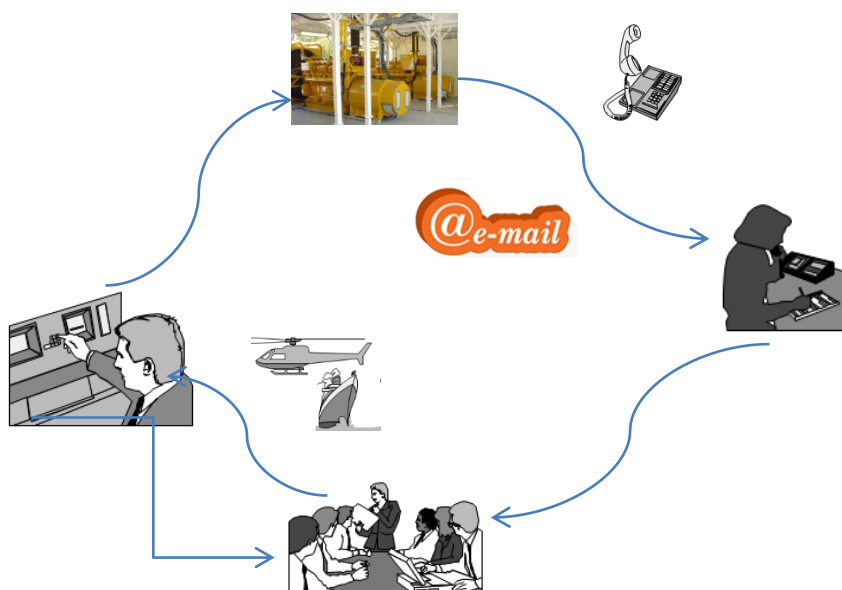


Figure 2-1 Conventional onshore support services

The diesel engines have to be inspected periodically by onshore maintenance team or OEM. If some failures happen, the offshore engineer often reports the failures through E-mail or telephone. As the real time efficient and effective communication is really difficult to ensure, 80% of the easy problems cannot be solved by this (from company engineer interview). Then onshore maintenance team communicate with the manufactures or subcontractors and send the site engineer to offshore for service if it is needed. Time value and cost is really a problem because of the weather condition, the time in helicopter or boat and the downtime lost. For some terrible problems that is difficult to solve, the site engineers may go offshore several times as no engineer know everything in the world.

To maintain the oil field services companies' competitiveness, a more cost-effective and high-tech planted maintenance solution is quite needed in the diversified manufacturing. The cost and profit should be evaluated from a long time circle; only get the contract first with a higher competitiveness, the profit can be achieved.

2.2 Remote support services using condition monitoring and online sensors

2.2.1 Model of remote support services

The remote support service can be one equipment condition monitoring and control or a whole system (integrated operations and e-maintenance). The remote support system can be divided into three parts: remote condition monitoring system, long distance data transmission system, decision-making and control system. These part cooperate with each other to achieve the remote control, the model can be showed in the figure 2-2.

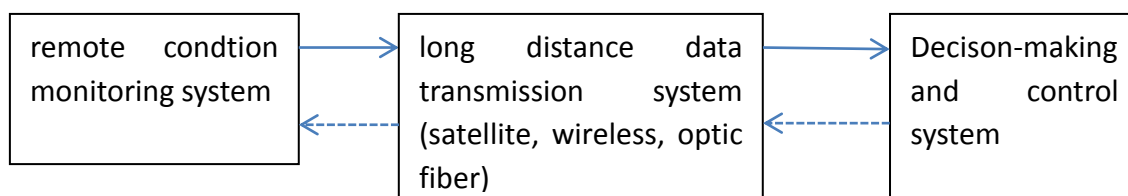


Figure 2-2 Model of remote support system

2.2.2 Remote support services in offshore oilfield development

The remote support services using condition monitoring and online sensor, especially

(integrated operations and e-maintenance) are winning great attention as an effective and efficient way in offshore oilfield development. In this section, we will discuss how things are done in Norway for example in drilling processes such as ConocoPhillips, Statoil and BP's support centers in Stavanger, SKF's remote support and others as well.

2.2.2.1 COSL's remote support services

In today's COSL, the condition monitoring and sensor data are restricted in the center control room offshore, to composite an effective remote support services system to onshore control center, some process, networking, security, hardware and software infrastructures are needed. The hardware includes the intelligent sensors and transducers, industrial PC, internet, intelligent watchdog agents etc. The software includes the database system, data communication and management software, decision support and making system, invented instruments using software instead of hardware instruments, etc. The same engine failure example using remote support services are showed in figure 2-3.

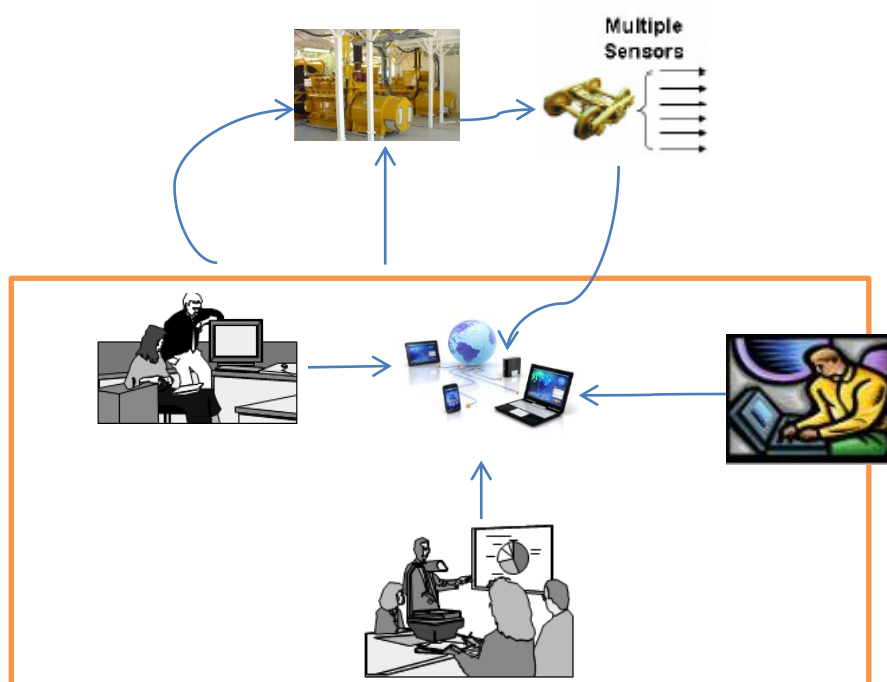


Figure 2-3 remote support services using condition monitoring and online sensors

We can get that different operational managers, decision makers can get the information from the internet everywhere in real time, where access to real time data and analysis can lead to gains in productivity and efficiency(Landgren et al., 2008). Then the trouble-shooting can be made quickly and direct the onshore engineer to recover the failure. Furthermore, because of the remote condition monitoring, some failures can be

predicted and change some spare parts in advance and then the failure can be avoided.

In some restricted area such as Iraq, the support services and resources are quite limited, the only solution is get the equipment information from internet and analyzed by domestic engineers, and then some predictive maintenance will be given without dangerous and/or expensive failure consequences. For some failures, the experts give some directions for troubleshooting. Iraq base of production optimization department of COSL is now contacting with SKF Shanghai condition monitoring center, they can install the condition monitoring system on the assets, and then they can supply the monitoring and diagnosis services for COSL. The online condition monitoring is not continuous condition monitoring, the data collection has many conditions such as speed, load etc. there are two reasons:

- Ensure the truth of the data
- Avoid some useless data to the database and make the data processing difficult

2.2.2.2 SKF's solution

SKF developed integrated condition monitoring (tools and technologies) for optimizing machine maintenance and reliability. For the bearing, although we now using maintenance-free bearing, there are also 36% bearing failure before time because of wrong lubricants or insufficient lubrication, so the condition monitoring are needed especially for some critical equipment.

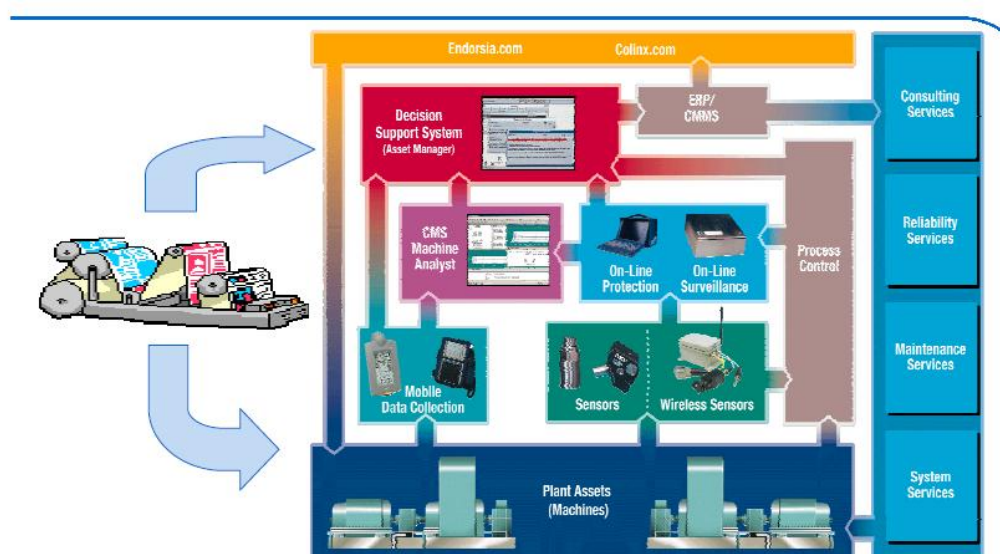


Figure 2-4 equipment reliability services from SKF (SKF website)

In Norway, SKF developed the remote condition monitoring for the offshore platform. Big screens in the monitoring centers and portable computers can get the offshore information and data for consulting services, reliability services, maintenance services and system services showed in the figure 2-4. The users can get not only the products of SKF, but also many exclusive benefits and options.

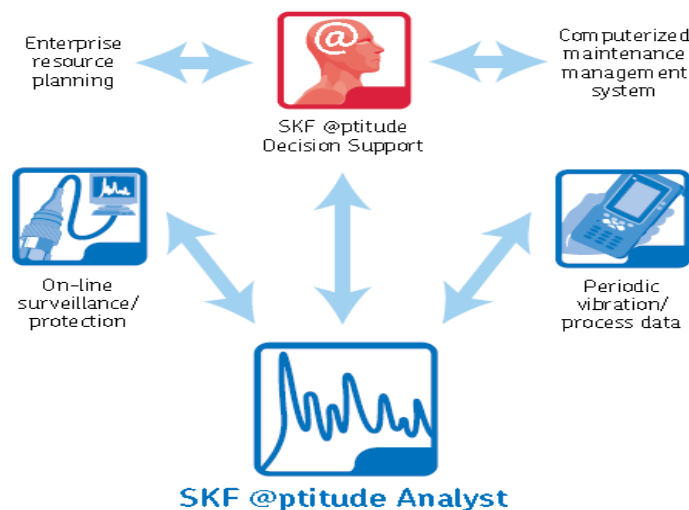


Figure 2-5 SKF @ptitude Asset management system(SKF, 2013b)

The system has a good connection with the CMMS system for the other function lines such as inventory management etc. CMMS (computerized maintenance management system) can make better spare parts logistics and inventory control through the condition of the equipment. For example, if the condition of the equipment changes (the performance is decreasing), the Min/max number of the spare parts will increase, if the number of spare parts number achieves the minimum level, an automatic purchasing request will be sent to the buyer.

For remote services, the condition monitoring measurements in SKF can be used by sophisticated software to predict a potential catastrophic failure. Besides, there are many benefits include:

- Capital investment cost savings
- Increased data integrity
- Expert SKF analysis and recommendations
- Global, 24/7 access to reports and data



Figure 2-6 Remote services of SKF(SKF, 2013b)

The potential cost for lost productivity for pumps and motors is low, but for the turbine, generators and other critical equipment, the downtime will be quite valuable, and the lost production by the downtime is beyond estimation, the continuous condition monitoring is quite welcome for prognostics to avoid catastrophic failures.

2.2.2.3 ABB's remote support Services

ABB can supply remote support services using ABB servicePort which is a remote-enabled service interface that provides your process control system an on-site connection to ABB process automation experts(ABB, 2013). The experts can predict the failure or diagnose where the problems are during trouble shooting, then direct the maintenance man to follow the steps to solve the problems.

The ServicePort is a remote-enabled service delivery platform that provides process automation systems with a secure connection to ABB services and expertise. Acting as an on-site service guide, it enables delivery of local and remote services and provides access to the latest ABB system and process diagnostics (ABB, 2013). By continuously monitoring system and process variables, ServicePort creates a rich data pool to analyze and troubleshoot system and process issues. Viewable Key Performance Indicators (KPIs) help the customer to drive and implement performance improvements faster and more efficiently(ABB, 2013).

The ABB ServicePort can give access to a wide range of ABB process control professionals and valuable services, including system developers, control tuning experts, troubleshooting technicians, software and application engineers, and system health analysts all of which are showed in the figure 2-7(ABB, 2013).

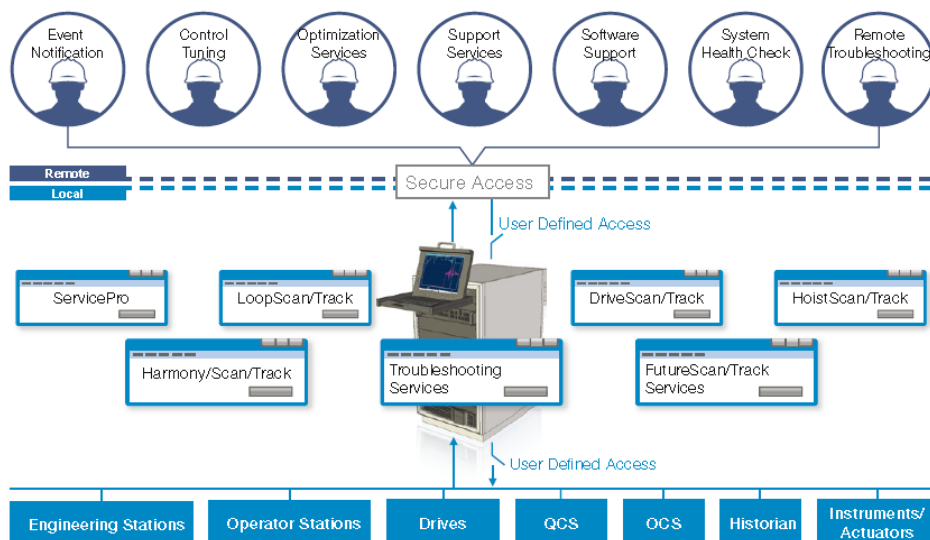


Figure 2-7 ABB's ServicePort(ABB, 2013)

2.2.3 Outsourcing and subcontractors in the remote support services

Bennett and Kmetz(2003)stated that “As part of a larger maintenance strategy, outsourcing the diagnostics and monitoring of critical machinery can be an effective tool in the battle to maximize asset availability and plant efficiency. In situations in which machine performance is critical but in-house analysis is not practical because of limited resources, outsourcing offers a cost-effective solution.” “Competitive pressures and the loss of key personnel through retirement and cost reducing operations are causing many companies to look closely at subcontracting their condition monitoring and asset management functions, says Scott Teerlinck, of Rockwell’s Plant Services business. They do this so they can focus on their own core competencies. This trend has caused condition monitoring and asset management to grow into a multi-billion dollar business. In 2005 the ARC Advisory Group predicted the worldwide market for Plant Asset Management (PAM) systems would grow nearly 10% per annum, from \$1.1 billion to more than \$1.8 billion by 2009.”(controlengineering, 2007).

In the author’s company (COSL) as an oilfield services company, the main resources are on the oilfield optimization and equipment management, outsourcing the condition monitoring and remote diagnosis is really a cost-effective solution. Furthermore, COSL can utilize the resources from different specialized company to realize effective equipment management avoiding large investment as some of the largest control and process management vendors are adding these services to their portfolios(controlengineering, 2007). Also in India, many large Indian companies are

frustrated at having to keep rebuilding their CM capability and are now resorting to outsourcing their CM services(Hills, 2006). The utilization factor of expensive condition monitoring instruments can be greatly enhanced if these kinds of work are outsourced to the services vendors.

Outsourcing CM can be an effective business strategy for many organizations but it is also fraught with risk(Hills, 2006). “The services vendors must be qualified to understand their clients’ business and their production processes. Providing a service that is inclusive of how they can best add value to their clients’ businesses must be their prime consideration.”(Hills, 2006). On the basis, the vendors have to be carefully audited to prove they have the advanced and calibrated instrument, analysis software and tools.

2.3 Comparisons between conventional and remote support services

Remote support services fulfill new needs and provides various benefits in form of increased efficiency, reduced lifecycle cost and increased customer value, which is quite a great opportunity for its development. However, we can only find quite a few users globally or the definition of the “remote” are quite different. The reason for that is lack of basis supportings to remote support including initial investment, training of technique and senior management and complicated design with all essential components.

- **Initial investment**

For small companies or plants, the big amount of initial investment and payback time are baffled the decion-making on the application. In fact, a small system can be initiated first with low investment and some branches of the system can be added graually using money saved from this and yearly budget. In all surveyed cases, the benefits derived from using remote support services have offset the capital equipment costs required to implement the program within 5 to 10years because the operation cost will be greatly saved showed in the figure 2-8. For the long run, the remote support services should be tried step by step. Also, the system can be invested together with some other companies including the oil company, subcontractors and other service companies. The CEO of COSL, Mr. Liyong stated that COSL can test the predictive maintenance using condition monitoring in one drilling rig initially.

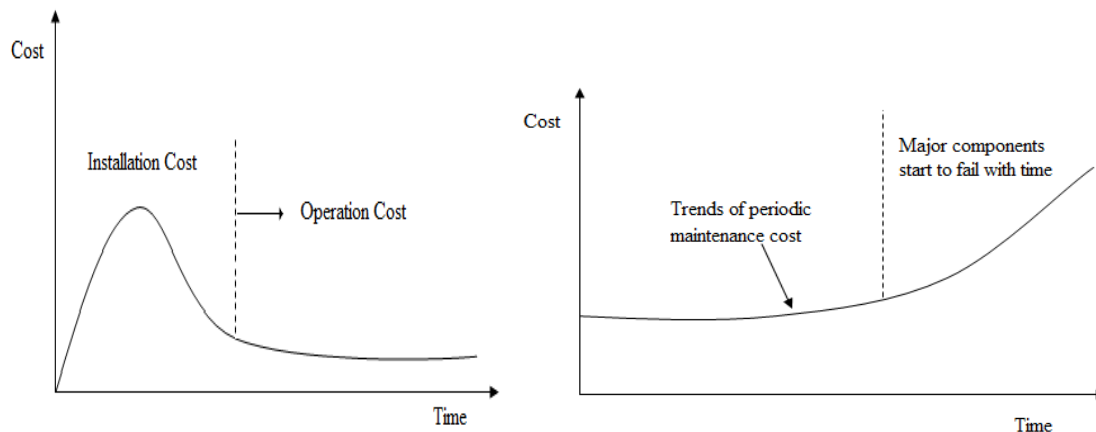


Figure 2-8 condition monitoring program cost(Left) VS periodic maintenance cost (right)(Mobley, 2002)

- False reading from the instruments (sensors): sometimes, instruments used to detect equipment's fault may fail and gives a false indication, therefore, it is very important to check the sensors whether they are working perfectly or not every time(IAEA, 2007).
- Senior management and technique
High level managers need have an overview of the system as they will make critical decisions on that. The senior managers must realize the efficiency and cost-effective of the system or lack of management commitment and involvement is the primary reason that most remote support services can't be created.
- Training to employees
Technique training to employees especially experts and technicians are quite essential in the development. Proficiently use of this system is the last but the important step of the system which decides the efficiency even failure or not. So training has to be given for maintenance personnel to make sure they are familiar with the technologies and software required for data collection and processing(IAEA, 2007).
- The IT requirement necessary to deliver a “ready to run” services.
For example, in the gulf of Thailand information super highway, “The bandwidth for subsea section is 2 GBPS (traversing in both directions to fully utilize the circuit), with 200 Mbps for terrestrial connection. The 200Mbps was chosen to comply with projected capacity required for anticipated future operations. The terrestrial capacity is tended to increase subject to actual future requirement.”(Senivongse et al., 2011). The IT requirement is difficult for some companies as the satellite band rent rate is quite high and has some unreliability problems as the satellite is prone to sun outage. The submarine fiber optic cable is also expensive and restricted by the distance.

The cost consideration is the primary concern for the corporate and its relevant stakeholders. We compare from the cost perspective although it is not easy. The remote support services have the large initial cost, but the annual system operation and maintenance cost are expected to decrease significantly in the remote condition monitoring support services. At the same time, the other direct and indirect benefits are also important. The oil and gas industry is so special, the QHSE performance is winning more attention than the economical aspects.

“The direct benefits, which could be expected from the real-time data transmission, are as follows:

- Instant access to real-time data for reporting, analysis and decision making at both operational and management levels.
- Ability to maintain nominated production level by avoiding the deferment.
- Reduction of Drilling NPT which would result in significant savings in operations
- Reduction of logistics costs which includes the helicopter and accommodation cost for avoidable offshore missions
- The utilization of domain experts and skilled personnel both offshore and onshore.
- The safety alerts and maintenance monitoring system can be implemented and will definitely improve safety of operations.
- Scarcity of knowledge engineers in E&P industries forced us to find a new way to better utilize the existing staffs as well as to build the young, less-experience ones. Collaboration over the telecommunication channels will help lessen this program.”(Senivongse et al., 2011).
- Predict the TTF(Time to Failure), make our mode of work become to pre-active (planned maintenance) without break down. The effect of this can be showed in the figure 2-9.
- Reduce the need of staff to attend the site in person work in danger zone.

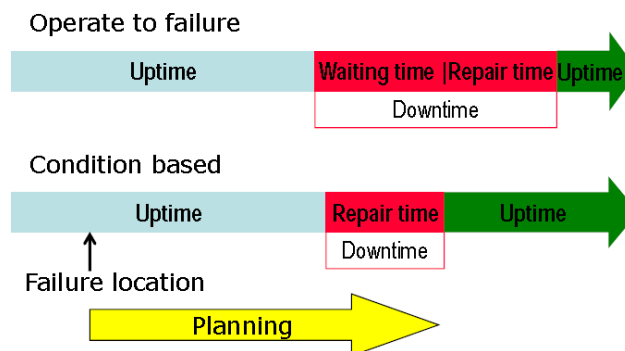


Figure 2-9 effect of condition monitoring(Markeset, 2012)

For the indirect benefits, some value-savings are not easy to calculate from the avoiding some risk and severe accidents to personnel and equipment. Furthermore, the service reputation is really important in winning the service contracts. Senivongse (2011) stated that the indirect benefits also include the improvements in work processes or current practices and better collaboration among offshore and onshore personnel, staff development through knowledge sharing and superior data management. Moreover, improved multimedia services will improve the quality of life of the personnel offshore. On the other side, several factors have retarded advances in the development of condition monitoring systems, including inappropriate choice of sensor signals and their utilization, and their inability to perform robustly in noisy environments(Silva et al., 2007)

2.4 Conclusion

Which alternatives are chosen for the maintenance and operation strategy are partly decided by the criticality of equipment, failure speed(showed in figure 2-10), the life circle cost consideration, management team and so on.

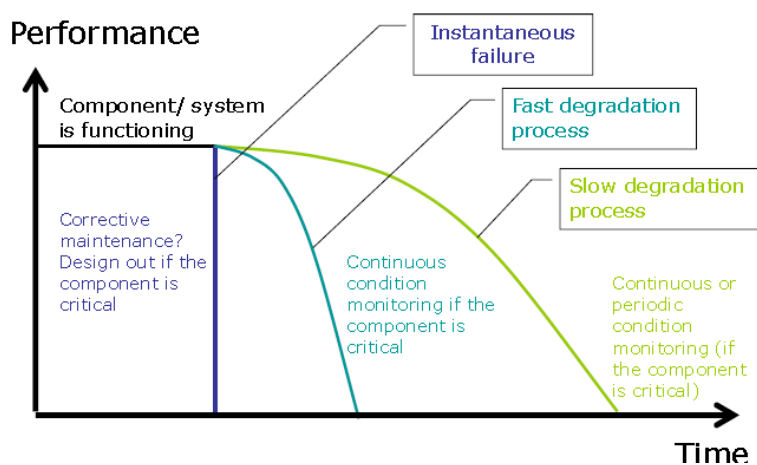


Figure 2-10 Speed of failure process decides the condition monitoring type(Markeset, 2012)

The remote support services will be more and more popular and become an important part in the oil and gas industry with the ICT development to achieve higher safety performance. The popular e-maintenance enables four main different maintenance strategies such as: remote maintenance, predictive maintenance, real-time maintenance and collaborative maintenance. We can see more from the modern corporate equipment maintenance management hierarchy (system) showed in the figure 2-11.

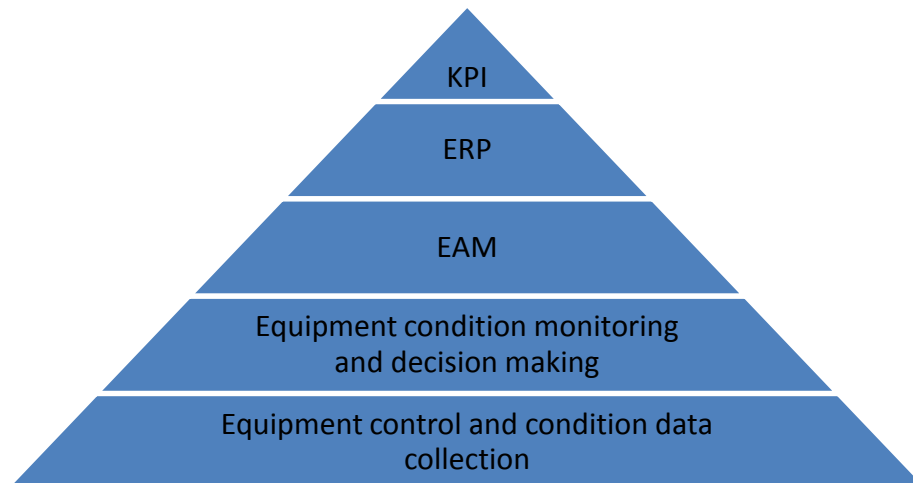


Figure 2-11 modern equipment management hierarchy (system)

There are five stages:

- Stage 1: PLC/DCS, online/offline condition monitoring
- Stage 2: analysis and diagnosis, decision making
- Stage 3: assets management and process management
- Stage 4: financial management, stock management, procurement management and relationships with other department
- Stage 5: Key performance management and decision making for the overall production performance.

The condition monitoring for maintenance is the first stage for the optimizing workflow and further decision making. The integrated operations is the term for the whole operation and management in the oil and gas industry which is started in 2006 by oljeindustriens landsforening (OLF). “Integrated operations (IO) is about employing real time data and new technology to remove barriers between disciplines, expert groups and the company”(statoil, 2011). The integrated operations is a proactive, parallel approach by multi disciplines and the decisions are based on real time data without the physical location restrictions. The following figure 2-12 shows the

comparisons between conventional work processes versus IO work processes.

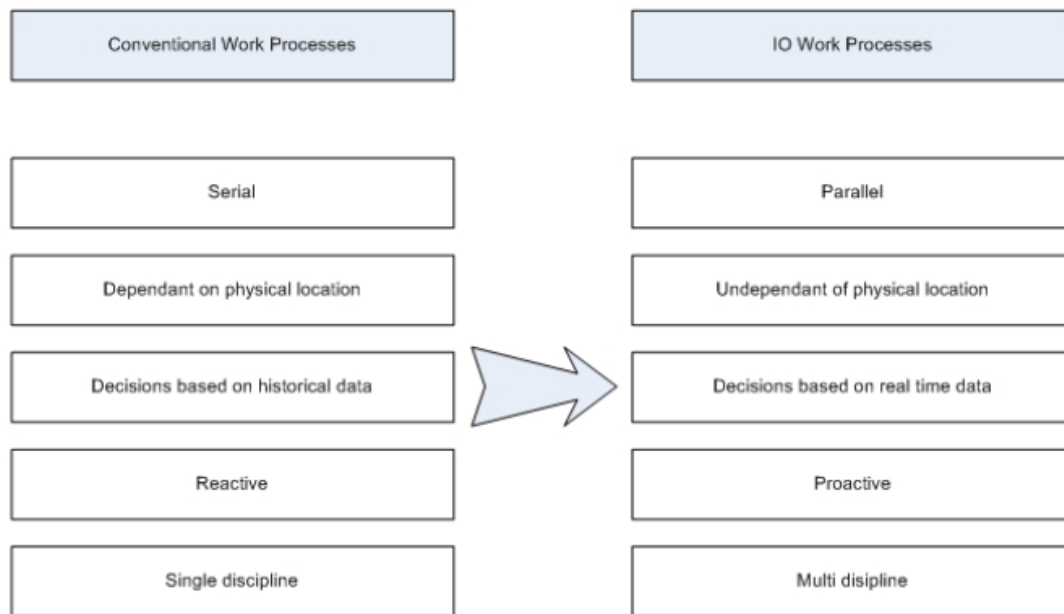


Figure 2-12 Conventional work process VS IO work processes(Hauge, 2011)

Why is the remote support services such as e-operations on the agenda? The focus on the efficiency and teamwork make the people start to use the new ICT technology to realize it. The benefits are visible but it is also facing many challenges which will also be discussed in this thesis. For example, there is a need for technological equipment that was compatible with each other within the company but also with the external companies like the service providers, there were several differences between the operator companies and the service providers(Hauge, 2011). How to make the company information security and how to manage the outsourcings need more work to be conducted.

Based on all the discussions above, the popularity and benefits of the remote support services cannot prove it is so successful in the operations and maintenance work, the KPI and safety assessment is difficult to evaluate and these are quite different in different oil field with different features.

3 The components and process of the remote support service

The remote support service for offshore oilfield is particular in the internet connection with the help of satellite showed in the figure 3-1. The different kinds of sensors collect the data and transmitted by the RS485 to the intelligent industrial computer. Then the data can be transferred through the internet to onshore monitoring office and these data can also be shared by multi-contractors and product suppliers. “The interaction between offshore and onshore, between the technical disciplines and between ConocoPhillips and our contractors significantly improve when you break functional barriers and interact.” (Kinmonth, 2012).

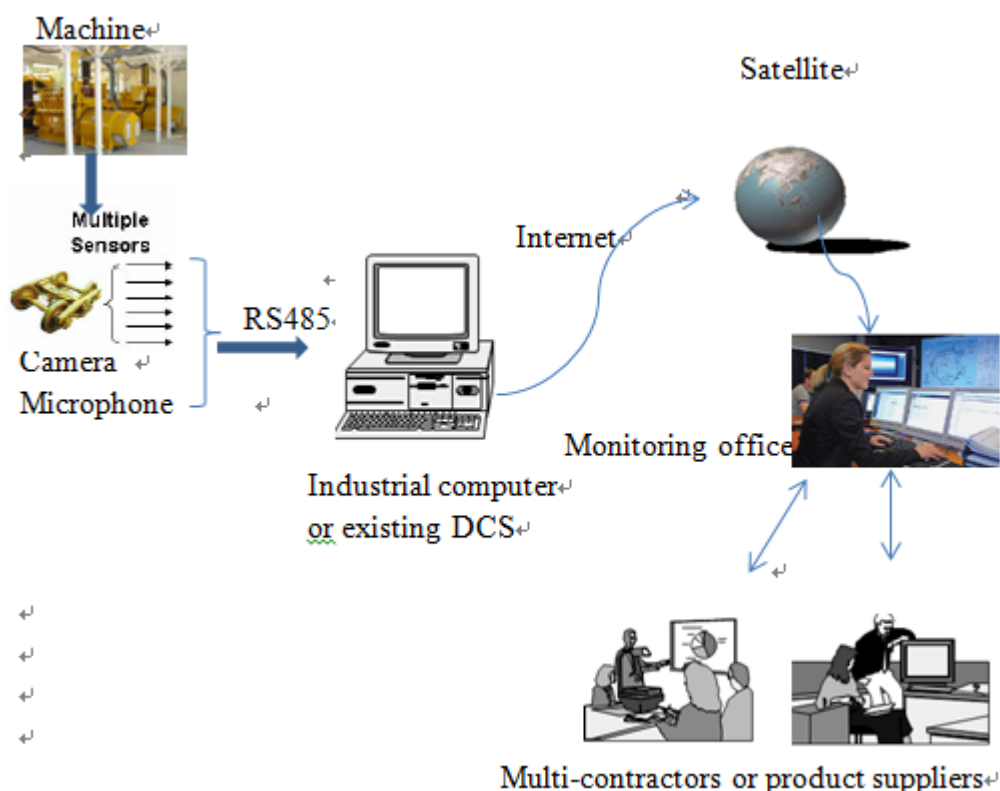


Figure 3-1 process of the remote support service for offshore oilfield

3.1 Sensors and transducers

In online condition monitoring system, the system have to periodic or continuously

monitor the running parameters, conditions and fault information, then analyze, process these data for decision making. Also some control orders from the upper management have to be transmitted to the equipment. Intelligent sensors and transducers have the features including quick action, automation integrated and self-testing logics and reporting capabilities, which greatly increase the reliability and response speed in the online condition monitoring system.

According to the standard IEEE1451.2, the sensors have the capabilities of integrated Ethernet and auto web connection even plug and play. The vast reduction in the cost of electronics and the development of the new micro-technologies has opened up new possibilities in sensor technology:

- The sensor's size has been greatly reduced, which make it easy to be installed in the machines.
- The cost of the sensors has been greatly reduced and it will become increasingly cost-effective for the whole condition monitoring system.

3.2 Intelligent watchdog agents

Watchdog Agents assess and predict the process or equipment performance based on the inputs from the sensors mounted on it. Performance-related information is extracted from multiple sensor inputs through signal processing, feature extraction and sensor fusion techniques. Historical behavior of process signatures is utilized to predict their behavior and thus forecast the process or machine performance. Based on the forecasted performance, proactive maintenance can be facilitated through the prediction of potential failure before it occurs. Furthermore, this proactive maintenance infrastructure can be supported by the information learnt at Watchdog and this Peer to Peer (P2P) paradigm will be utilized to improve diagnostic and forecasting functionalities of the Watchdog.

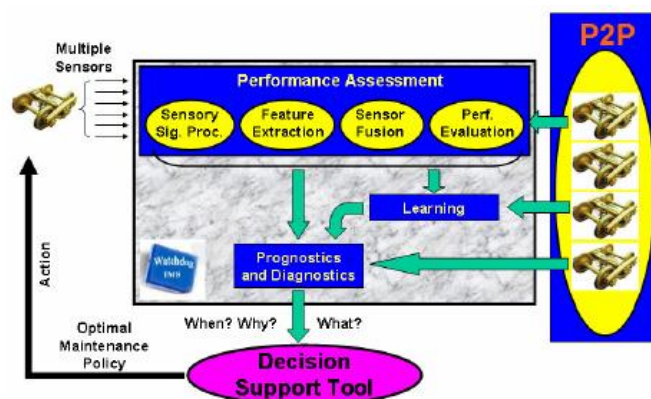


Figure 3-2 Functionality of the Watchdog(NSF, 2013)

The three functions of Watchdog Agent (showed in the figure 3-3) can be utilized to increase the availability of the equipment while preserving the environments through reducing the energy consumption and ecological product reuse.

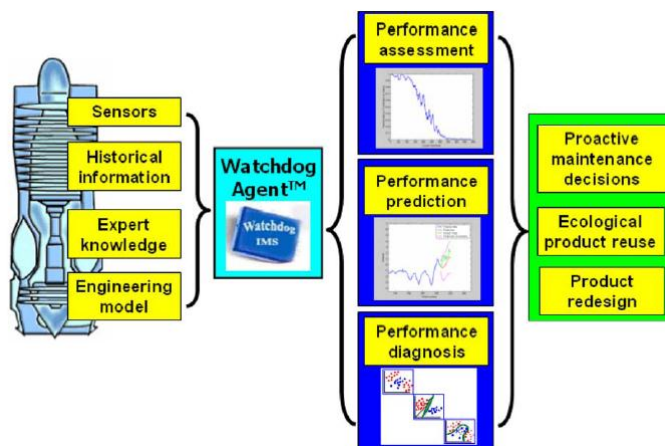


Figure 3-3 Three functions of Watchdog Agent(Djurđjanovic et al., 2003)

3.3 Industrial computer or DCS system

In offshore platform, we are using the industrial computer or DCS system to monitor some parameters of our equipment offshore. The operation and maintenance team can check the data periodically or some alarms will appear if something is wrong. In order to achieve near-zero down-time and the best possible quality of products and services in contemporary markets, it becomes increasingly important to predict and prevent process or services failures and thus follow the proactive Predict and Prevent (PAP) maintenance paradigm, instead of the currently prevalent Fail and Fix (FAF) maintenance paradigm mirrored in reactively addressing and fixing the failure once it occurs(NSF, 2013). So we just want to transfer these data to onshore for condition monitoring and diagnosis to improve reliability, productivity, and asset utilization.

“The elements of a DCS may connect directly to physical equipment such as switches, pumps and valves or they may work through an intermediate system such as a SCADA system.” The difference between a DCS and a SCADA is often subtle, especially with advances in technology allowing the functionality of each to overlap. The following figure 3-4 showed a typical DCS control system. The data can be transferred to onshore for online condition monitoring.

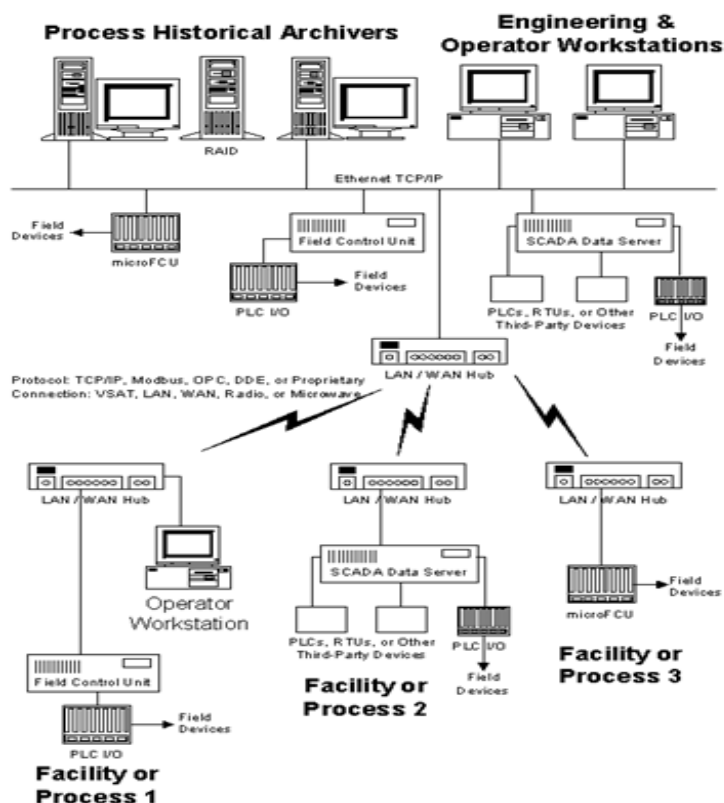


Figure 3-4 Typical DCS system (COSL’s internal document)

3.4 Internet connection

Internet connection is critical for the online remote support system. From offshore to onshore, we can use the satellite or optic fiber to connect. While for onshore stakeholders in different locations, the telephone line or ADSL Tele-service can be used with a VPN (Virtual Private Network) channel. Here is an example from Siemens for this showed in figure 3-5.

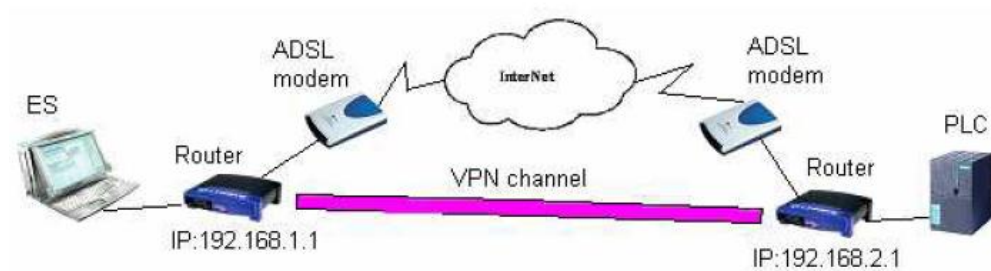


Figure 3-5 ADSL Tele-service configurations Chart

3.5 Wireless computer applications such as smart PDAs and

Mobile devices

Comparing with the traditional wired computer applications, the wireless computer applications have many advantages. Adding the ease and flexibility of carrying a handheld wireless device, mobile computing has the potential to transform the way a range of industrial management, monitoring and control tasks are performed (Buse and Wu, 2004). However, the integration of equipment, devices and computing resources make the application still in the infancy period.

3.6 Data computing and information management

Maintenance working conditions are characterized by information overload (manuals, forms, videos, real-time data), collaboration with suppliers and operators, integration of different sources of data (drawings, components, models, historical data, reparation activities) (Holmberg et al., 2010). So how to manage the data and make decisions is the vital part of the system. Holmberg (2010) stated an architecture OSA-CBM (open system architecture for condition based maintenance) as an open non-proprietary CBM communications framework to provide a functional platform flexible enough to suit a broad range of applications, showed in the figure 3-6.

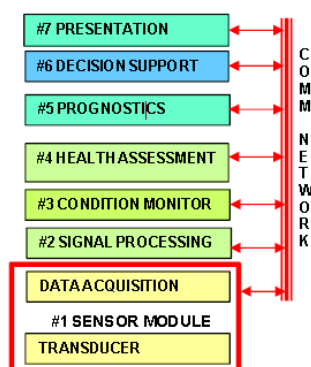


Figure 3-6 OSA-CBM layers (Holmberg et al., 2010)

The data collection and management should be well treated by some softwares. For example, SKF have a @ptitude analyst which can provides fast, efficient and reliable storage, analysis and retrieval of complex asset information and makes the information accessible throughout the entire organization, the data can be seamlessly interfaced with CMMS, enterprise resource Planning (ERP) and other information management systems.

3.7 Integrated operation and maintenance support centers

“A number of new and updated centers have started up, for example Production Optimization, Integrated Planning and Logistics. Future developments include HSE and Well Integrity centers in ConocoPhillips of Norway”(Kinmonth, 2012). In the maintenance support centers, all the running parameters, data, videos can be monitored and different contractors and other organizations can analyze and diagnose using software or experience. SKF’s website(SKF, 2013a) showed that “once machine reliability data has been collected, the data needs to be analyzed. In sending the machine data via the communication system to an SKF remote diagnosis center, the data is monitored and interpreted by certified machine reliability experts. Depending on the operator’s needs, SKF can create customized reports that detail identified potential problems, recommend appropriate actions, and facilitate the scheduling of maintenance procedures.” The following figure 3-7 (Kinmonth, 2012) shows the maintenance support centers in ConocoPhillips of Norway. In this center, the onshore drilling center has large operation rooms with big screens where they displayed real time drilling data, such as depth, weight on bit, string torque, mud weight in/out and gas levels(Hauge, 2011). The visualization and collaboration make the downtime reduce because of well planning.



Figure 3-7 maintenance support centers in ConocoPhillips of Norway(Kinmonth, 2012)

3.8 Condition monitoring optimization

The condition monitoring can be continuous or periodic based on the condition of the equipment. The condition monitoring plan can be optimized continuously. Here is an example on the transfer pump SB3"x4" J-9-1/2". There are six parameters need to be monitored to predict the failure of the pump showed in figure 3-8 and figure3-9.

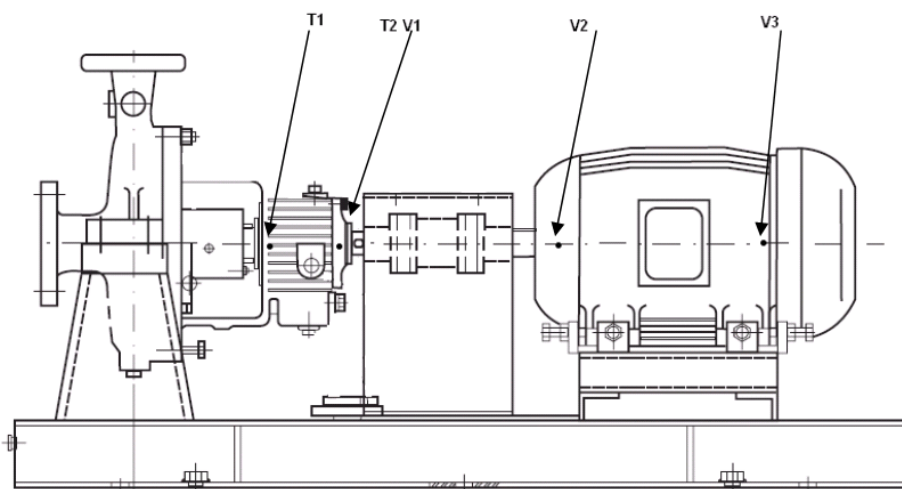


Figure 3-8 condition monitoring on transfer pump SB3"x4" J-9-1/2

trend analysis for transfer pump SB3"x4" J-9-1/2"

Tag:		K1-24P-JCA-X-QA-0000007						Lubricate Interval:	
Name:		transfer pump SB3"x4" J-9-1/2"						Lubricate Quantity:	
Date	S P E C MAX	Current	T1	T2	V1	V2	V3	Duty Hour (Hours)	Enclouse
		(A)	(°C)	(°C)	(mm/s RMS)	(mm/s RMS)	(mm/s RMS)		
2010/5/7		15.1	45	48	1.6	1.8	1.2		
2010/5/13		14	47	45	1.7	1.8	1.3		
2010/5/19		15.5	50	47	1.5	1.8	1.2		
2010/5/25		15	48	46	2	1.8	1.4		
2010/6/2		16	66	67	1.3	1.8	1.6		
2010/6/10		15.5	62	66	1.4	1.8	1.7		
2010/6/18		16.4	65.8	66.8	1.3	1.8	1.6		
2010/6/24		15.3	65.2	66.5	1.5	1.8	1.7		

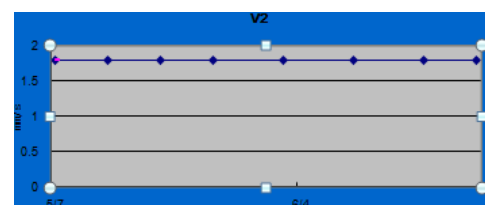
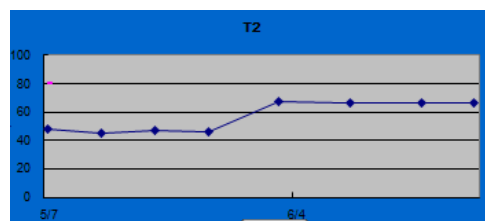


Figure 3-9 trend analysis of the transfer pump

The vibration of the mud pump V2 is quite stable if the monitoring interval is one week. So the interval for V2 can be optimized to 2 weeks or one month. However, the temperature T2 has a raise from 40°C to 60°C or so, then the optimized monitoring interval should be shorten to 3 days even 1day inspection. All in all, the monitoring plan should be optimized in order to create more values from this process showed in figure 3-10.

How to judge the data is OK or not? It is difficult for the manpower to find it from the curve. So the plant health database should be set up and the monitoring data can be compared with the health data to find the abnormal point, then the experts can focus on it in real time. For example, an automatic triggered warning, email or a work order will generate when a reading indicates that boundaries are exceeded or something abnormal happens.

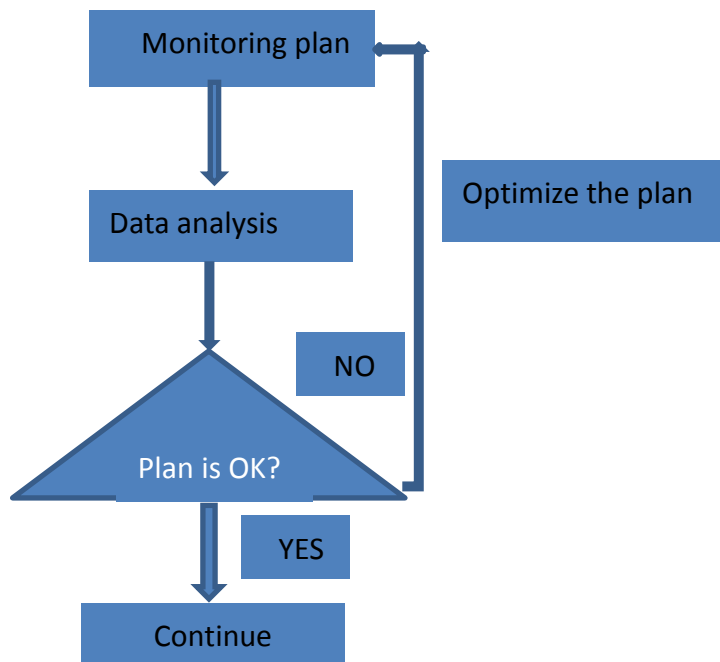


Figure 3-10 the monitoring plan optimization process

During data analysis process, the data has to be compared with the Meta data, and then get the validated data and call for action showed in figure 3-11.

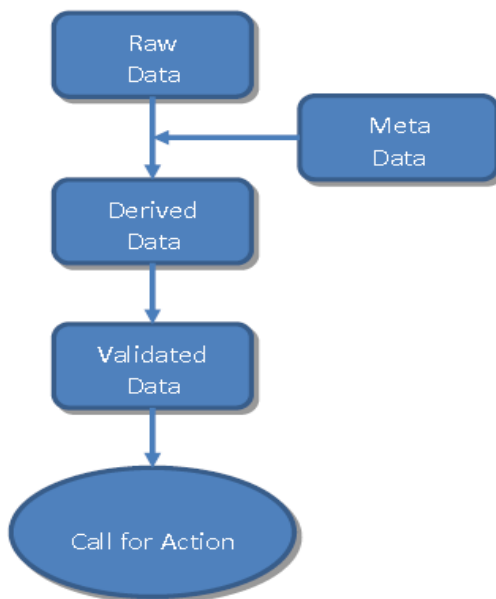


Figure 3-11 DATA ANALYSIS PROCESS

Dagnev(2012) also stated an integration of condition monitoring data with historical data to optimize maintenance time interval showed in the figure 3-12.

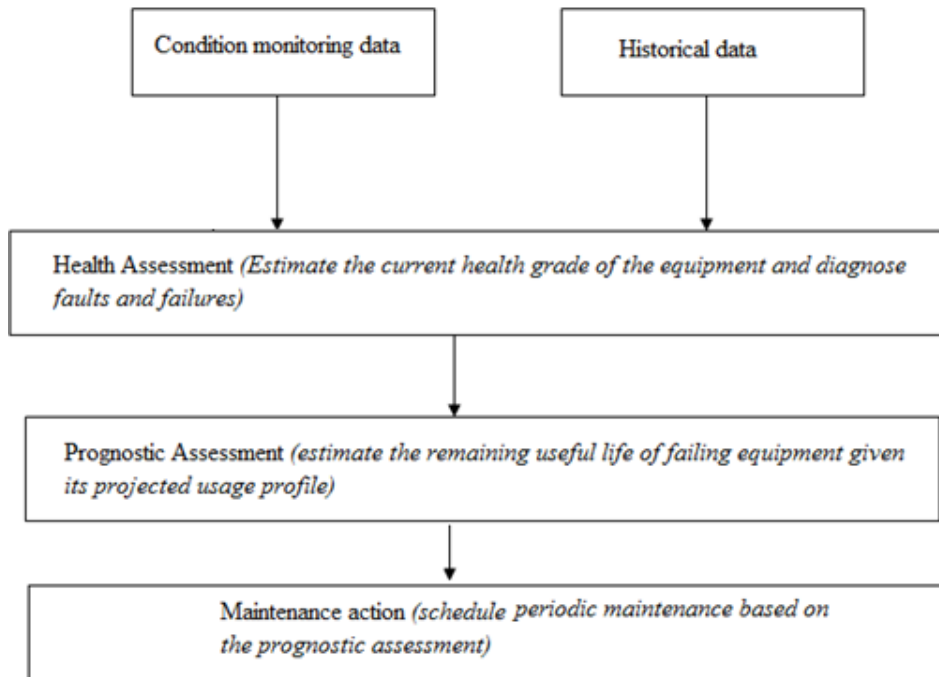


Figure 3-12 integration of condition monitoring data with historical data to optimize maintenance time interval(Dagneu, 2012)

3.9 System safety including Access to data and drawings

When the Corrective maintenance services are outsourced to vendors, the system safety should be paid great attention. Some IT requirement should be met to ensure security of data and drawings. The single ticketing system should be initiated to management the access to the data.

All of the system management means great resources and large investments. To solve this problem, “ a business model that makes sense would be neither centralized nor decentralized, but would rather be a hybrid model, where common costs would initially be reallocated to the business units, and where business units could buy products and services at well-known rates, and over time, could transition to a pay per usage model.”(Landgren et al., 2008).

3.10 E-training for the remote support system

With the development of ICT, the training can be implemented anywhere, it is a kind of web-based training. E-learning has redefined the way education is provided in schools, academia and industry(Holmberg et al., 2010). E-learning users, both teachers/trainers and students/learners are offered integrated solutions that facilitate authoring,

structuring and delivering educational content, as well as assessing the educational outcome, such solutions are termed learning management systems(Holmberg et al., 2010). There are some advantages of e-training:

- Through the e-training, the new employees can learn the operation and maintenance without go offshore for offshore oil and gas industry, which can reduce the hazard exposure.
- The time and location for learning is also flexible. For example, vocational training in maintenance
- Learners are free to navigate through the material and choose the courses that they need.

E-training is not only a flexible and cost-effective training, but also an interesting and effective team-building tool. Conferencing, mailing, bulletin boards, chat and forum are among the additional features that are typically integrated with the learning environment and content(Holmberg et al., 2010).

3.11 Conclusion

Great progresses have been made in all the components of the remote support services recently. Current practices are testing and optimizing to achieve better performance in the equipment availability, life circle cost and overall production. How to integrate this component including technology and organizational issues will be a challenge and are winning great attention in the academic study.

4. Case study of current practices in CNOOC of remote support services technology

4.1 Types of traditional remote onshore support services in CNOOC

- PM procedures composition and review. The support team work on the PM procedures and the offshore maintenance team conduct the procedures periodically (yearly or monthly). A sample PM procedure used in the author's company are showed in the figure 4-1.

DSU 6M PM			
Author: LI GEN	Approved by: (Name): Billy Chen	Permanent: XX Temporary: .. Temp. Expiration: ..	
Document Owner: (Job Title): Drilling Engineer		Review Frequency: 3 Y	
Legacy Document Name: ..		Legacy Document Number: ..	Created On: .. 30 Jan 2007
Procedure Type: Electrical	Frequency: 6M	SAP Task List Code: ..	
Minimum Craft Grade to perform procedure: Electrician		Number of Persons Required: 2	Total Man Hours: 5

NOTES:..

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Maintenance procedures are scheduled by a computerized maintenance management system (CMMS), which follows manufacturer recommendations and follows ConocoPhillips China HSE, MS, and Permit to Work systems. Maintenance procedures are subject to continuous improvement. Required changes are redlined on existing documents and sent to the Document Owner for review. Approved changes will be implemented and the next revision initiated...

Figure 4-1 A sample PM procedure

SPIR parts and safety stock setup. The spare parts inventory record are not based on the real time condition of the equipment but the engineer's experiences. The min/max stock level are also from the experience and offshore engineer's Material request list, which is really rely on the capabilities of the engineer. With the development of MM(mateial management) module in ERP and CMMS, the stock and spare parts management have changed a lot, but only restricted in the equipment department, Maintenance mission accomplishment should be in phase with production environment performances, in this way, maintenance require the cooperation of, and association with, virtually every department (production, procurement, engineering, accounting, human resources, etc.) in the plant, especially with production(Holmberg et al., 2010). So the SPIR and safety

stock work flow need to be optimized with the development of e-maintenance. Figure 4-2 shows a SPIR list the onshore support team made. But the quantity including the min/max stock have to be optimized with the decision making of different department. Normally, a large spares inventory is necessary to ensure quick repair(Holmberg et al., 2010).

SPARE PARTS AND INTERCHANGEABILITY RECORD (SPIR)										PR13978164					
DCWR_C ACS800 Multi-drive system has two ACS800-507-2720-7 DSU unit, four ACS800-107-1160-7 and one ACS800-107-1740-7 inverter, and two ACS800-607-1600-7 braking chopper.										Equipment Description ABB AC800 Multi-Drive syste					
PARTS SUPPLIER FOR JOB SITE (AFTER ORDER SERVICE)										Equipment Manufacturer ABB					
NAME: ABB										Sellers name And Address					
ADDRESS:										PREPARED BY:					
PHONE / FAX:										PHONE QUOTATION NO.					
23 PARTS REORDER INFORMATION										QUANTITY					
NOTE: SELLER MUST ATTACH TO THIS SPIR FORM ALL SECTION DRAWINGS AND PARTS LISTS SHOWING ALL PARTS RECOMMENDED FOR PURCHASE										Min Item Level	Min Item Stock	Catalogue (SAP) Number	Unit Price		
SPIR Item Number	Multi-Quantities	Top Job or other	REORDER POINT	Description of Part	Filter	reparable	Original Manufacturer	Original Manufacturer's part Number	Cert Type	Q required	2 Year Ops	Min Item Level	Min Item Stock	Catalogue (SAP) Number	Unit Price
1	ea			ACS800-107-1740-7/ACS800-107-1160-7		9	10	11	d Not	12	1	1	1	15	16
2	ea			FUSE SWITCH,OESL630/32D24, FUSE,170M8650,1000A,1000V/900A,1000V				3AFE64787047 3AFE64673769				0	0	1.1E+07	6075.9 224.96

Figure 4-2 SPIR list sample

Mobilize the contractors to go offshore for corrective maintenance or predictive maintenance. If the contractors cannot solve the problems based on the failure description, the site service engineers from the contractors will be sent to offshore to conduct the work based on the work order(showed in the figure 4-3)

JL88-MPH-030

**EXHIBIT H
FORM OF WORK RELEASE ORDER**

To: Jutal offshore oil services limited	Work Release Order No.: DCWR-C-2009-06	REV No.:0
Contact: Mr.He shigang	Contract No.: PBO 6-139	
Tele No.: 022/66282241/66282242	Date: 2009.02.16	
Fax No.: 022/66282240	AFE/GL: 702015	
	Charge Code: BX2312	
	Originator: John zhang	

*This Work Release Order is subject to the terms and conditions of Master Services Agreement No: PBO 6-139.
* For imported items please mark **Yes** or **No** and indicate whether customs assistance is required **Yes** or **No**.

Scope of Work/ Mob / Supply of :

IBOP valve repairing

1. Take 2ea IBOP valve (M&M16410 PAT. 5246203) from COPC onshore warehouse.
2. Disassemble and maintain this valve.
3. Provide repairing proposal、service plan、 necessary drawings、 material list and budgetary estimate to COPC drilling dept. for their review and approval before any further work begins.
4. Contact COPC engineer to clarify any question while conducting this work.
5. Test this IBOP valve and confirm that it can work safely and smoothly.
6. Return 1ea IBOP valve to COPC onshore warehouse.
7. Record all such work steps, during the course of the work. This will be compiled into a final report. The report should include any recommendations and any suggestions for future operation
8. Provide three copies of the work report to COPC onshore drilling dept.
9. COPC will provide necessary data as needed to assist this work.

Rig B site survey for EATON brake air control loop

1. Mobilize one engineer with full PPE and special tools to WHP B to conduct site survey.
2. Survey and make draft drawing for this control loop.
3. List all valve, adapters and hose quantity and manufactory.
4. Contact COPC engineer to clarify any question while conducting this work.
5. Provide three copies of the work report (include draft drawing, valve and adapter list) to COPC onshore drilling dept.
6. COPC will provide necessary tools and personnel as needed to assist offshore work.

Figure 4-3 Work Orer

The PdM(predictive detective maintenance) are mainly on the oil sample analysis, here is the procedures and testing method showed in the figure 4-4.By doing these test we will be able to make RCFA and then trend analysis can be performed. But the online sensors for the oil test have not been utilized.

Pulling the sample:

Choose a container that matches the volume requirement. Make sure it is new or clean. Pull a representative sample of the oil, preferably while the equipment is running or immediately after shutdown. Try to pull from the middle of a reservoir to get a representative sample. If pulling from a valve, clean it thoroughly and then let the oil run for a moment before collecting the sample.

Identifying the sample:

Fill out the attached form with all the information about the sample. Make sure to include the lube oil type, and grade, the size of the reservoir, the name and tag number of the equipment the sample is from. All of these factors greatly impact the recommendations we get based on the raw data from the analysis.

Sending the sample back:

Pack and box the sample, including either absorbent or some other material that will absorb oil in case of leakage during shipment. Please send the MSDS sheet along with the sample also.

Packing:

Pack the samples to a suitable case, mark the outside with:

1. Handle with care.
2. Glasses, fragile.
3. Keep upright.
4. Flammable material.

Figure 4-4 Oil sample analysis

4.2 Current condition monitoring and remote support services in

CNOOC

The different kinds of condition monitoring are widely applied in the offshore oilfield platforms in CNOOC including vibration, oil inspection and analysis(CSI5200),belt tension monitoring, motor static monitoring(EMCAZTPRO2005) and other condition monitoring on the specific equipment by the OEM. From 2007, the technical inspection company of CNOOC started to test the online condition monitoring system on offshore production platforms, monitoring some critical equipment such as the water injection, efflux pump running status and etc.

The condition monitoring has been used for stock management. “Each item in stock is analyzed according to certain criteria and it joins the corresponding storage policy. The criteria are: Spare parts value-usage (affiliation with A, B, C group), Criticality (affiliation with V, E, D group), Frequency of demand (affiliation F,S,N group)”(Bosnjakovic, 2010). How to decide which spare parts should be analyzed to V, D, E, A, B, S, F, N or S (the classification refer to appendix B)? The condition monitoring of the equipment make it possible to connect with the CMMS system and optimized the stock with the classification of stock.

The audio and video transmission system by satellite for offshore oil and gas industry operation are also widely utilized in CNOOC. The video conferences can greatly increase the interaction among all the parties. The daily meeting can be much more effective and efficient in the information sharing and planning. All the parties know what kinds of work are being done. For example, if something on the drill floor needs maintenance then instead of stopping the drilling operation, the rig crew can perform

this maintenance when they are doing an operation that is not performed on the drill floor i.e. while waiting on the casing cement to set up(Hauge, 2011). Besides, SCADA (supervisory control and data acquisition) system is used for data analysis and monitoring for LNG production.

Actually, there have been a lot of sensors and the data is available for decision making in CNOOC, but the people and organizations do not realize or have less knowledge to utilize these information to manage the maintenance and operation.

Here XPR 300 and RH2000 system will be introduced here.

4.2.1 XPR 300 System overview

XPR300 online system (showed in figure 4-5) is being used by the technical inspection company of CNOOC. “Based on Internet technology, OneproD XPR-300 can support condition monitoring techniques, such as infrared thermography, oil analysis and process data. The same database can include data from both Off-line (Movilog2, MVP-200, MVP-2EX or MVP-2C data collectors) and On-line (OneproD MVX system) measurements. In addition OPC Client and OPC Server options allow for On-line communication with process control in both directions.”(VibrationsteknikAB, 2013).

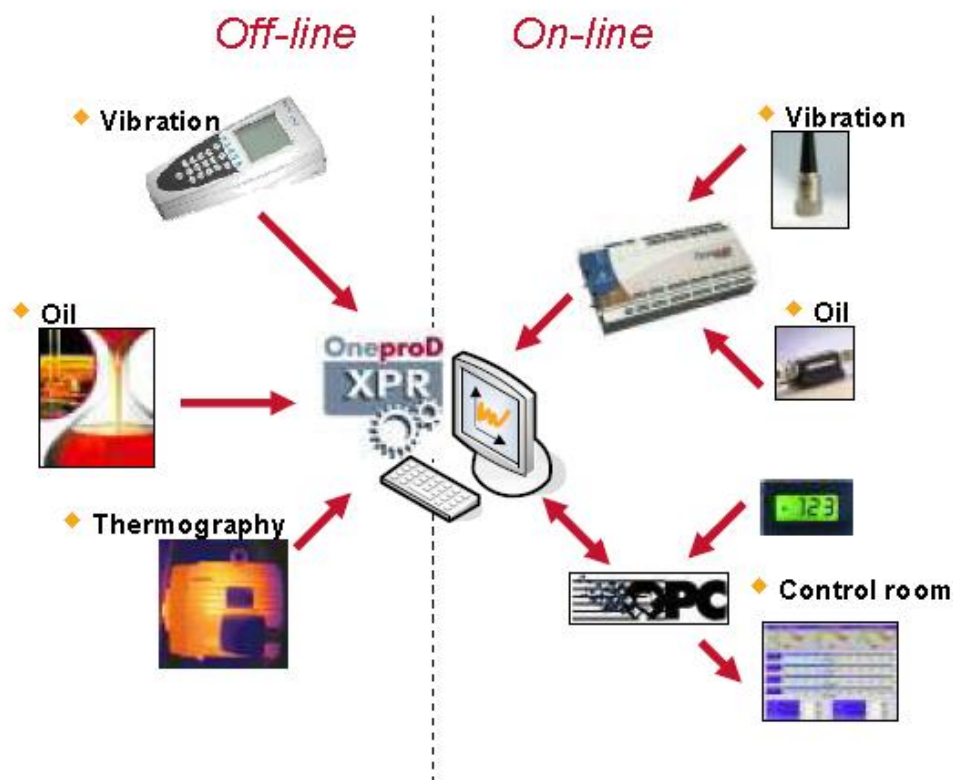


Figure 4-5 Available in three configurations, single station, client/server or Web, OneproD XPR-300 favors information sharing within and outside the company, and thus allowing a quick and efficient decision-making(VibrationsteknikAB, 2013).

The main body of the system is a web-based condition monitoring and diagnosis system, the others include the Oracle database software, online sensors and data access hardware. All the parameters are integrated to a common database, and then all the Ethernet users can visit the database server and read the current parameters and history data. There are the paralleled two output digital signals for data collection: one signal to PLC system via Modbus (RS485 or Modbus TCP/IP), the other can connect with the XPR300 software via RJ45 internet port(Yang and Lin, 2011).

4.2.2 RH2000 system

RH200 online condition monitoring (showed in figure 4-6) has been successful applied in the condition monitoring system. The technical inspection company of CNOOC can predict the failure of the equipment from the data collection and analysis, the alarm can be triggered if some abnormal happens. Both platform client and onshore client can monitor the running status and make decisions on the operation and maintenance.

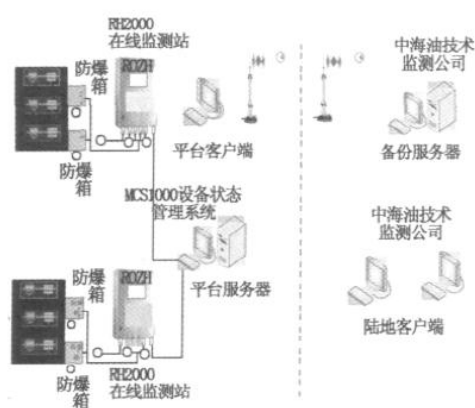


Figure 4-6 The RH200 system configuration(Yang and Lin, 2011)

From the two systems applied in CNOOC, we can find the following problems:

- The system is so small that only focus on some critical equipment's operation and maintenance. Only some parameters are monitored.
- The decision making process is not clear with the organization management. Decisions cannot be made without a clear process if the information is shared by all the departments and different opinions come out, and then the "real time" target will be affected. For example, the integrated operations or e-maintenance is a kind of teamwork which may have an "unintended effect" if it is not well-designed and managed. As the team is consisted of different individuals, they may have different interests, motivation, concerns, understanding and behaviors, etc. so it is easy to create tensions and conflicts among team

members. For example, there may be many opinions be considered, however, everybody promote their own, which makes time-consuming and difficult to make a decision. There are some common conditions that maybe one member down, everybody down, or one member not satisfy, the rest suffer.

- No connection exist with the workflow and ERP system, third party condition monitoring suppliers or maintenance management system. So no collaboration exists between multi-disciplines. Actually, workflows can be automated and processed through a platform generic messaging service that sends notification through SMS, E-mail and IM(Reid et al., 2006). For example, the Schneider's remote condition monitoring can connect with SAP system showed in the following figure 4-7.

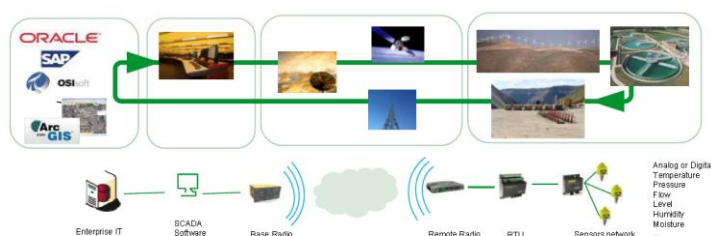


Figure 4-7 Schneider's remote monitoring connecting with SAP

- The system in CNOOC has not been independent of physical location. Only the onshore control room can monitor the process.

4.2.3 Condition monitoring for critical equipment on drilling platforms

On drilling platforms, the top drive and diesel engine are the critical equipment for the drilling operation. Currently, there are many parameters to be monitored for Top Drive such as bearing temperature of main motor, temperature of lubricants, pressure of lubricants and cooler air. Although the main shaft seldom has problems, the poor installation and accident may cause the main shaft deformed. So the condition monitoring apparatus is installed for the Top Drive. The challenge is that the top drive is connected with the drilling string which vibrates frequently with the well pressure, so it will be difficult to judge for the continuous condition monitoring.

One solution for the Top Drive vibration condition monitoring is comparing the condition when no drilling string is connected (NO LOAD). The condition monitoring can be conducted periodically and compare the performance curve with the normal curve. From this, some predictive maintenance can be implemented according to the

vibration change.

The vibration monitoring for the diesel engine, mud pump and other equipment should be conducted by offshore maintenance man and then send the record to onshore expert or service providers, they can diagnose for the equipment and give some feedbacks without service provider going to offshore, saving the mobilizing & demobilizing cost

4.2.4 Condition monitoring system in PL19-3 oilfield

PengLai19-3 Oilfield Phase II in bohai bay of China was developed in 2004, the VFD control system of the Drilling Completion and Workover Rig (DCWR) is ABB ACS800multi-drive system. 2EA ACS-800-507 DSU rectifying cabinets, 5EA ACS800 -107 inverting cabinets and 2EA ACS800-607 brake chopper units compose the 600V power &drive system in each DCWR. Totally there are 5EA DCWRs in PL19-3 oilfield, all the power &drive systems are the ACS800multi-drive system. The power distribution and VFD single line drawing showed in the Figure 4-8.

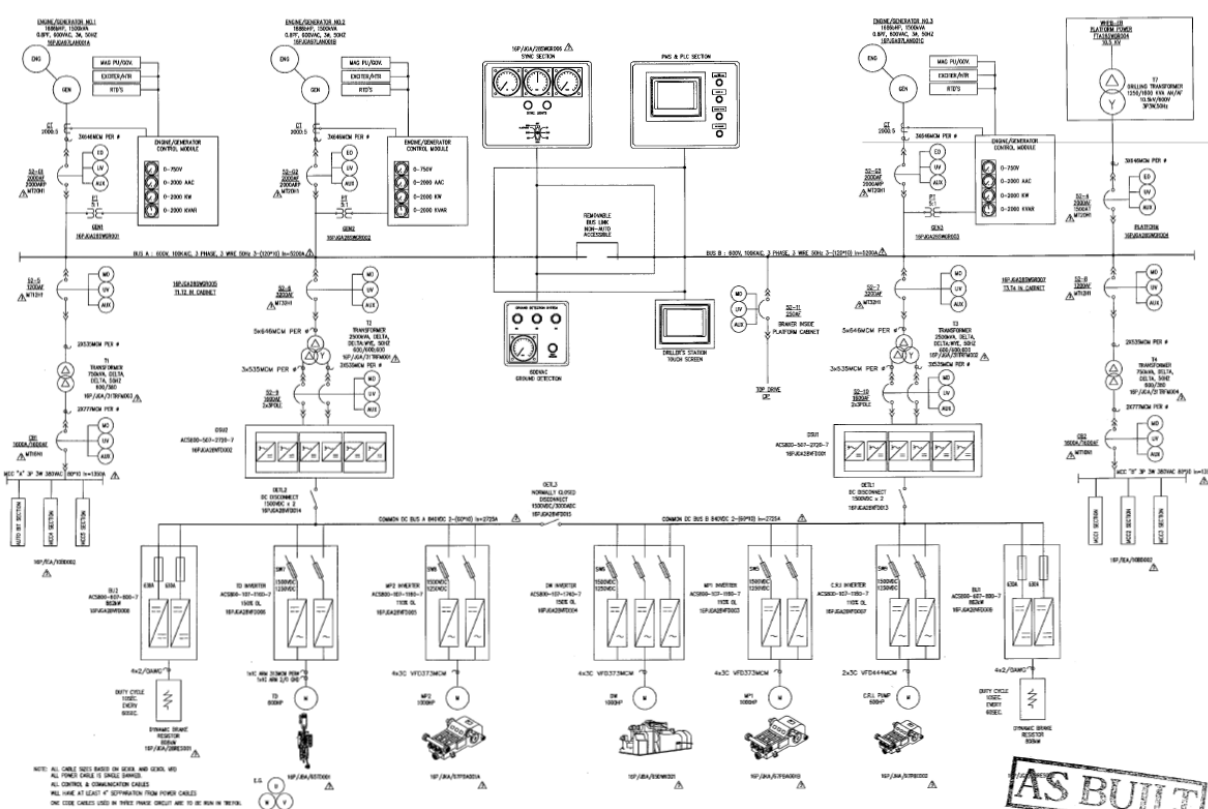


Figure 4-8 DCWR power system single line for PL19-3 oilfield, Bohai Bay

PengLai 19-3 oilfield phase II designed and constructed the VFD system without any online or remote monitor system, the site engineer just can use the control panel

(CDP312) to check the running data and warning&fault informations, then conduct the PM procedure as the user's guide manual. The site engineer know nothing about the status of the VFD system, so they cannot do anything before the VFD failure to control the motors.

Table 4-1 The cost statistics for ACS800multy-drive system in 2012

Platform	Down time (hours)	Operation Costs (USD)	Repair Costs (USD)	Totally Cost (USD)
DCWR B	72	360,000	10,000	370,000
DCWR C	63	315,000	8,000	323,000
DCWR D	66	330,000	8,500	338,500
DCWR E	40	200,000	4,000	204,000
DCWR F	47	235,000	5,000	240,000
Total	288	1,440,000	35,500	1,475,500

When the VFD system cannot drive the motors, the site engineer just get the fault information from the CDP312, the drilling operation has to be shutdown. The site engineer cannot get any trend analysis on the ABB ACS800 system, the company has to mobilize the service engineer from OEM(Original Equipment Manufacutrer) with spare parts to go offshore to repair the VFD system.

This solution increases the downtime, also increases the operation cost and the repair cost. The repair cost here include the outsourced maintenance services cost, spare parts cost to recover the multi-drive system. The operation cost includes the standby fees to different contractors and the other daily cost. It is relatively small comparing with the operation costs(only 2.1-2.7%). So the repair and maintenance cost is not the main cost for the drilling operation. The operation costs because of the downtime must be considered and the cost can be saved if the repar maintenance can be well planned without downtime. The statistics cost for ACS800multy-drive system in 2012 are showed in the table 4-1. From this table, we can get the total direct lost is about 1,475,500USD, almost 97% is the operation cost.

To reduce the operation cost, company has to improve the reliability of the VFD system first of all, secondly reduce the time of resume production for the VFD system. The ABB Serviceport can reduce downtime due to lower downtime and travel costs by service experts remote diagnosis, because the serviceport can monitor the VFD system and transfer the status from offshore platform to TangGu drilling office via the internet. The Figure 4-9 is the process of the ABB serviceport in PL19-3 oilfield.

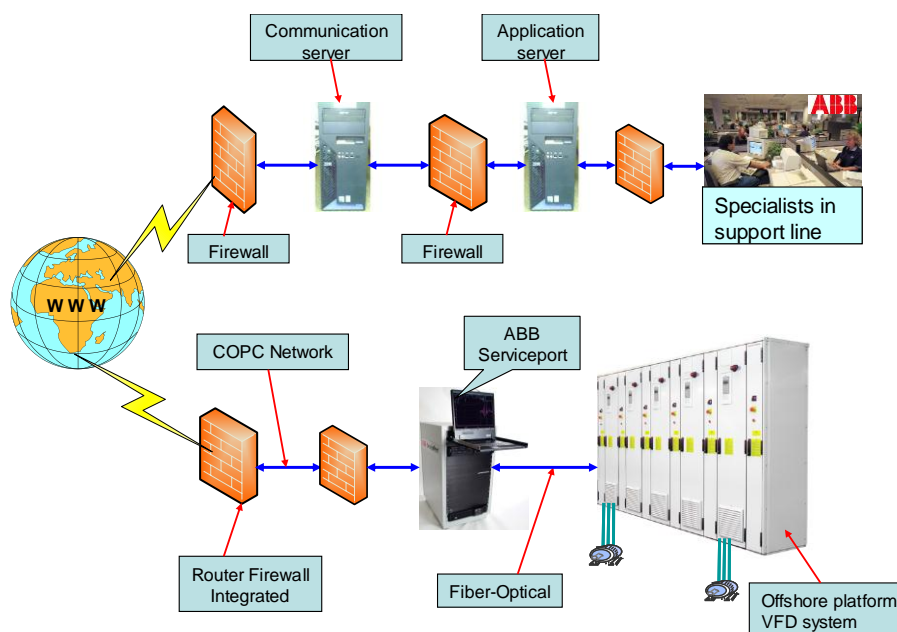


Figure 4-9 the process of the ABB serviceport in PL19-3 oilfield

The ABB serviceport can collect the real time data and transfer these data to onshore supports center via the COPC Network and the internet, the experts get the running data online and analyze the status of the VFD devices to optimize the control parameter (Refer to the figure 4-10). The serviceport can improve equipment and process performance and availability, help customers improve productivity and quality.

The most benefit of the serviceport is that it can predict the failure by monitoring the running data. When ServicePort transfer the abnormal running data to onshore, the specialist will analyze these abnormal running data and ask the site engineer to check the VFD system immediately. This work will keep the VFD system being functional and maximize system lifecycle in the future.

It also helps reduce raw material and energy costs. In addition, service costs are cut by providing access to ABB expertise remotely, reducing response time and travel expenses. To mobilize the ABB site service engineer to go offshore from support center need more than 24 hours in the past, with the serviceport help the company can reduce the downtime 24 hours at least each time, so COPC can cut the direct lost 120,000 USD, if the serviceport in function in 2012, COPC would reduce the direct lost at least 480,000 USD (4 times shutdown).

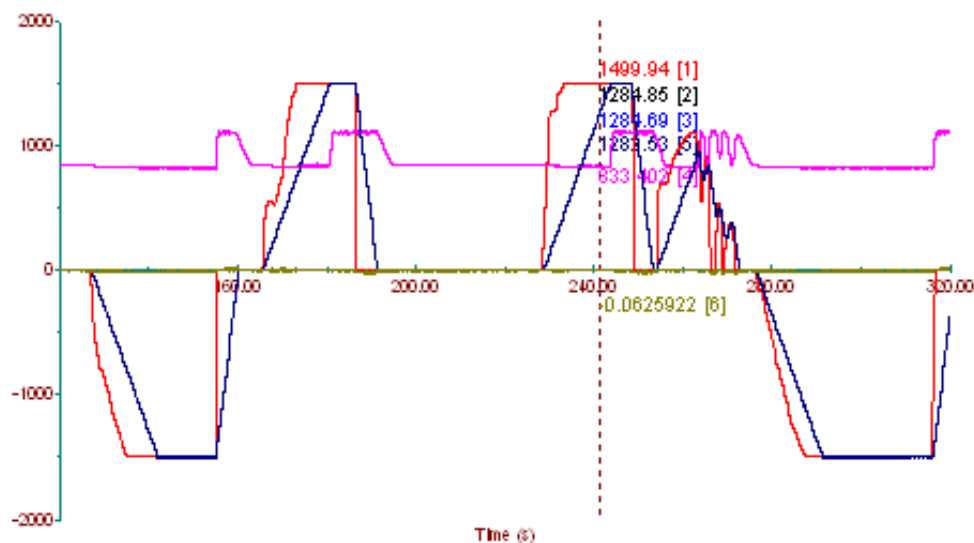


Figure 4-10 Running datas for the VFD system(single device)

In conclusion, the serviceport in PL19-3 oilfield delivers immediate access to services that can keep drilling operation continuously, maximize VFD system lifecycle, optimize process performance and deliver operational excellence. The onshore engineer can remotely control the VFD system with the serviceport. The application of the serviceport in PL 19-3 oilfield, improve the facility management level of the COPC, help the COPC comdcting the PM and PdM, reduce the downtime caused by VFD system and the production lost. This will be a great application for COPC in bohai Bay.

4.3 Conclusion

CNOOC is making great progress in the remote support services using condition monitoring and online sensor. But the E-maintenance on drilling and production platforms is still ZERO. There are some main reasons:

- The management culture change is difficult
- The initial cost and high satellite renting fees
- The basic predictive maintenance are not well performed, still stay at the scheduled preventive maintenance.

So the e-maintenance in CNOOC has been left behind by other competitors, but the trend of e-maintenance cannot be stopped which can greatly break the barriers between platform and onshore support center. Even though the overall e-maintenance is difficult, the periodic e-maintenance can be tried and tested which is also have great potential both for economic and other considerations.

5. The role of ICT in condition monitoring and online sensor data

Information and communications technology or information and communication technology (ICT), is often used as an extended synonym for information technology (IT), but is a more specific term that stresses the role of unified communications and the integration of telecommunications (telephone lines and wireless signals), intelligent web services, PDAs, industrial computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.

In the condition monitoring and online sensor data development, one of the most important step is share the information in real-time and geographically, furthermore, reliable and inexpensive communication is also the enterprise will consider. The ICT include pure technological advances in acquisition, communication and storage of information, to the identification of advanced information standards for system interoperability, such as MIMOSA and open system architecture for the condition based maintenance(Holmberg et al., 2010).

5.1 The impact of ICT technology

The impact of ICT technologies is considerable in the modern work life. Some of these impacts can be found in the ConocoPhillips's Integrated Operations development program. " ConocoPhillips in Norway is mixing one part oil with one part telecommunication, and adding talented people, to develop state-of-the-art Integrated Operations (IO) centers for Production and Well Operations in the Norwegian sector of the North Sea."(Kinmonth, 2012). In this program, the information and communication technology are used to integrate the well operation system through condition monitoring and remote control. The onshore integrated team is from all the contractors and Oil Company, they work in a team to achieve the operation performance. Here are some of the impacts from the practical example including both positive impacts and negative impacts:

- Work content and work organization. New role, responsibilities are set up and further to the organization change. The status of the equipment are transmitted by the information technology to the onshore computer screen, the experts and integrated maintenance team can work onshore without going offshore, the work

content is changing. Further, the responsibilities are becoming more integrated and the site routine works are beginning to vanish. It can be challenging for the organization to change the workers attitude towards the new organizational structure, especially if it is not clear to the employees why and how the organization want to implement the new organizational structure, and how this will benefit the employees, the company, owners and customers(Hauge, 2011).

- The ICT technology makes the work more effective and efficient. Mankin (Mankin et al., 1996) stated that “Team and new information technology can catalyze dramatic improvements in organizational performance” and “technology makes team more effective”. The ConocoPhillips integrated operation center also greatly increases the effectiveness and efficiency both in the normal operation and emergency trouble-shooting decision makings.
- The ICT technology makes the work become a team based work and knowledge based work.
- Transfer of knowledge and influence. The ICT technology make the knowledge transfer rapidly and make the personnel know the system easily and efficiently. The onshore experts can use distance education to teach the offshore technicians.
- Social contact and Communication patterns. From the interviews in ConocoPhillips Integrated Operation Center, some employees use the computer for the whole day which is really a negative impact for their social life.
- Increasing tempo. With the increasing tempo of work life, the stress factor to the workers should not be neglected. The high working stress has caused some physical and psychological effects to the workers. How to ensure enough leisure time and health is becoming an issue.

5.2 How to reduce the negative impact of ICT

In order to reduce the negative impacts, we have to look at the ICT from a systematic view for the overall performance. From this point, Social-technical design(Eason, 1992) for the information technology systems is a suitable approach to reduce the negative impacts of complex IT systems. The other sayings express the same meaning such as humanized approach, joint design, integration of the organization’s sociotechnical characteristics into the design, etc. (Liyanage, 2012).

- The system should be designed to serve the organizational goals, not only a technical system. Only from this, the higher performance can be achieved from the

team based work. For example, the social contact and communication are needed to a better teamwork.

- The system design will depend on all the relevant stakeholders in the design process(Eason, 1992). The wide range of knowledge from the organization will make the design to ensure human safety and reliability.
- Social-technical design also considers the human factors in the design. Social technical design will evaluate the human's need in the increasing tempo, the proper work time and enough leisure time will be considered. Or some safety and reliability problems will emerge.

The ICT technology greatly impacts the remote support services using condition monitoring to real-time data transmission. Wireless technology is one of the ICT technology and it is has been widely applied by the condition monitoring suppliers.

5.3 Satellite communication

Satellite communication has been proven to be an import, advantageous, reliable and flexible solution for data transmission in the remote support systems. Some of the most important benefits are showed below:

- Long distance transmission.
- Reliability.
- Capacity with many communication channels
- Vulnerability

For offshore oil and gas industry, it has many benefits from declining the cost of subsea cable installation and manpower's workload, and then the performance of safety can be greatly enhanced because of the people-oriented concept. By analyzing the development of satellite communications, IPSTAR is chosen as the satellite access network terminal, data transmission technology of OPC is applied to fulfill the integration between control network and information network(zhang, 2009).

However, the communication can also be slightly affected by the atmospheric phenomena. The equipment reliability and the skill of operating and maintenance personnel are also should be paid great attention for the satellite communications in the remote support systems.

5.4 Wireless technology in condition monitoring

Wireless technology is a new way to gather and transfer information, then analyzed by data logging computer to realize the online monitoring continuously or periodically rather than manually which can greatly reduce the downtime and improve safety. The wireless can be achieved through GPRS, Bluetooth, wireless network connection etc. The wireless technology has its advantages:

- No cable laying and connection, which can save cost and make the maintenance easy without cable cut down.
- The wireless sensing equipment and infrastructure is now robust enough and have begun to be integrated into large systems(controlengineering, 2007).
- The wireless technology can reach the area where the maintenance personnel can't reach.
- watch for trouble and allow maintenance personnel to intervene before equipment malfunctions(controlengineering, 2007)

The integration of wireless condition monitoring and internet systems can also cost-effective for some comprehensive systems. Early in 2002, Wang Jintao has developed the wireless distributed condition monitoring system using internet for remote support which showed in the following figure 5-1.

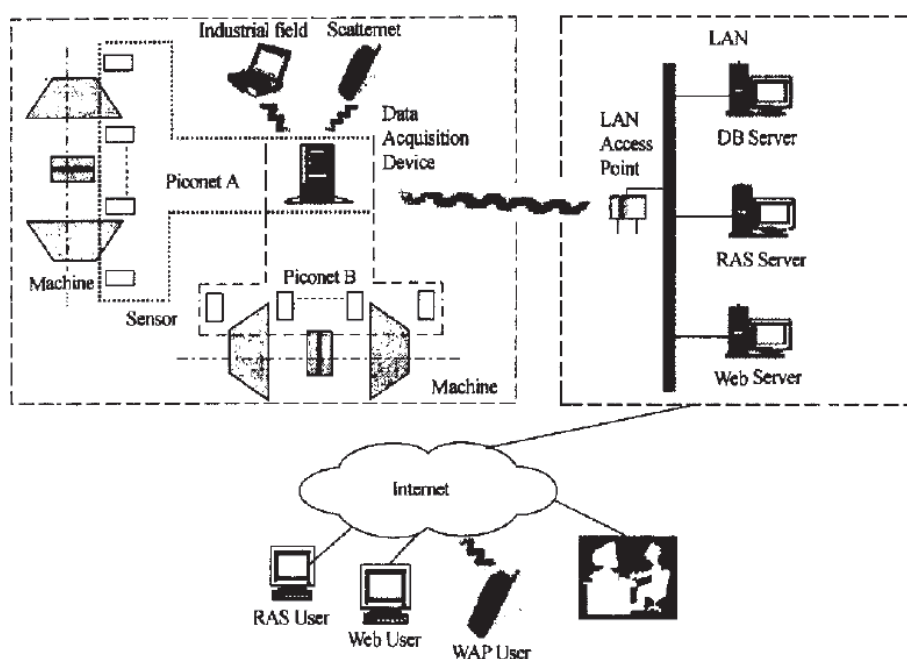


Figure5-1 system construct of wireless distributed condition monitoring system(Wang et al., 2002)

5.5 Conclusion

The ICT technologies have changed the conventional work process to a higher speed, easier and safer type. The future maintenance and operation can be finished without the restrictions of geographical location. The digital period will change the management culture in the near future.

6 Challenges and barriers for remote support services

6.1 Key operational workflow management

The remote support system needs the competent Employee and expert to collaborate around the workflows with a common objective, so the workflow is so critical in the system. The workflow is a process which needs integrated and streamlined management. For example, responsibilities need to be allocated and resources redistributed. Also the clear identification of workflow procedures is required such as reporting, assessment, feedback, documentation, and so on. A holistic and sequential management can facilitate the process whereas disordered management could bring negative influence. “ The current operational centers managing Well Operations, Production Optimization, Logistics, Integrated Planning and Project Management are fantastic examples of Integrated Operations in action”(Kinmonth, 2012). Different department will have some Interdependence which comes together with interactions, complexity, coordination and intra- and inter-organizational relations which can be showed in the figure 6-1. So the modern business operations will become complex. This complexity often results in different situations and problems, including benefits and shortcomings. At the initial phase, the cultural change is a difficult task until all the employees successfully grasp the workflow and get the benefits of the system.

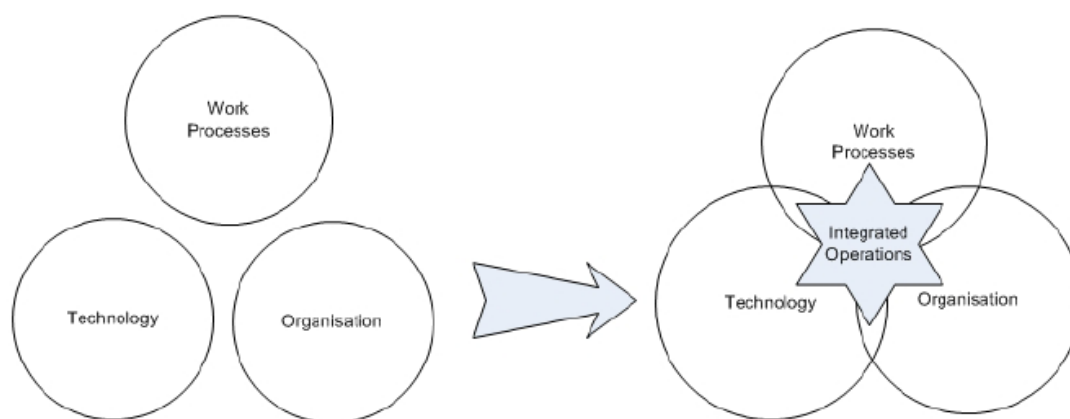


Figure 6-1 Illustration of integrated operations(Hauge, 2011)

6.2 Decision making

Firstly, the data and information collection will from different department, how to make

a decision making based on information from different aspects. The analyzed results may be different in different KPIs.

Secondly, the remote support services should decentralize the decision making rights to the reliable experts. “In highly centralized work systems, formal decision making is concentrated in a relatively few individual groups or level, usually high in the organization, in the decentralized work system, the decisions are delegated downward to the lowest level having the necessary expertise.”(Hendrick and Kleiner, 2002).

Thirdly, the decision making rights should be authorized to employees with proper supervision. MacFarlane and Flynn (MacFarlane and Flynn, 1993) introduced the term of Enhanced Organizational Teamwork(EOT). Well educated employees must be given both incentives as well as decision making powers. In other words, they want to involve in the process of business running and performance management. So the decision making and performance management process should be changed to more involvements which are not only improves business, but also obtains employee commitment to business objectives.

6.3 Information logistics

The information logistics is here understood as the practices of providing the right information to the right actor, at the right time, place, format and cost(Haftor et al., 2010). The key contribution of information logistics is therefore to provide the right information about an industrial entity to the needing actors, whether human or machine(Haftor et al., 2010).

How to manage the information to be shared by the right person, how to manage the information by filter the information is still a challenge for the remote support system using condition monitoring and online sensor data.

6.4 Departmental and Technology integration

Reid(2006) stated that the industry challenge with respect to technology is reportedly not the absence of suitable technology but the need for automation and integration of available technology in order to realize promised benefits. The technology in their own area such as data collection, data analysis, internet, and ERP have developed to a high level, but the integration of this technology to suit for a specific industry is now facing different problems, that is why the remote support services are not widely applied.

For the departmental integration, let us see an example: we have had the CMMS

(computerized materials management system) for spare parts management, but how to link the system to the Predictive maintenance system and condition monitoring, how to link the system not only to the equipment management department, but also to the operation and marketing department for the overall decision making. Spare parts management is a cooperative effort, in order to ensure an efficient system, all elements, such as maintenance, engineering, purchasing must be aware of the overall objectives (Bretz and Gerard Schram, 2010). The spare parts management is not just computer software, but more on the departmental cooperation.

6.5 The balanced development of human, organization and technology and the related safety

The remote support services with high-technology seem to have a great economical potential and make the oil and gas exploration safer. But if the people and organization do not prepare well, the system will face many safety issues. If the people cannot understand and use the system proficiently, some HSE-related incidents may happen. So a balanced development among people, technology and organization is needed to ensure safety.

The ergonomics should be considered during the system design for the safety and high efficiency. General macro ergonomics is given: Macro ergonomics or “human-organization-environment-machine interface technology” has emerged in order to interface organizational design with technology to optimize human-system functioning. Macro ergonomics is a top-down sociotechnical systems approach to the design of organizations, work systems, and jobs and considers four inter-related subsystems: the personnel subsystems, technological subsystem, organizational structure and the external environment (Ringstad and Andersen, 2007). “Fit the job to the human” is just the guiding philosophy of ergonomics (Bridger, 1995). So it should be “fit the job to the human” that lead to safe and productive human performance. From figure 6-2 (UK government HSE, 2012) list the accident model, we find the human failures come from the person, organization and job (technology complexity).

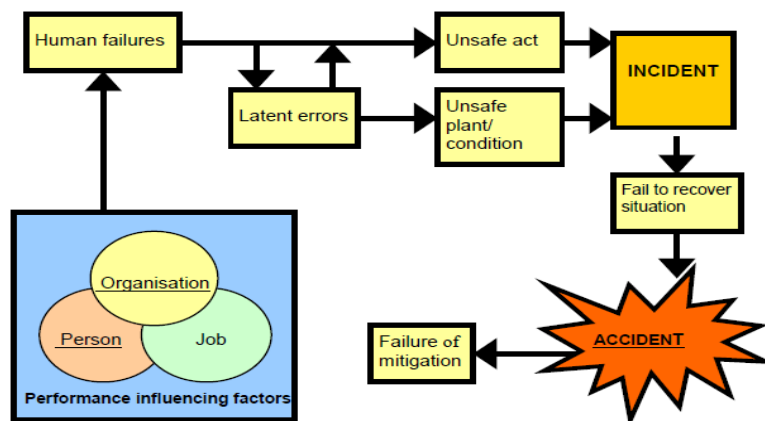


Figure 6-2 Accident model source from UK government HSE

6.6 Key equipment selection

The remote support services should be conducted initially for the key equipment. It is not possible to perform condition based maintenance for all systems/equipment in the plant, critical and suitable equipment must be selected for condition based maintenance program(Dagneu, 2012). The methodology used for the selection process is illustrated in figure 6-3.

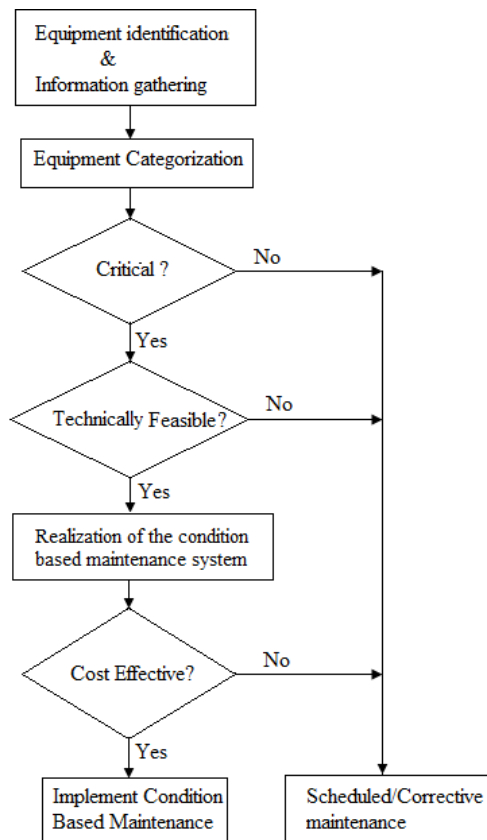


Figure 6-3: A method for selecting suitable equipment for CBM(Dagneu, 2012)

6.7 Conclusion

From the upper discussion, the main challenges focus not on the technological aspects, but the organizational and management aspects. Practice makes perfect! The companies can make “trial-error” efforts to build-up experiences and optimize the working process.

Other challenges will be not discussed here, such as the initial cost, sensors failure, etc. The initial cost has been offset by the enhanced availability of the equipment and less downtime. Technologies have made great progress in sensors although sensors not always tell the truth.

7 Possibilities of remote support services using condition monitoring and online sensor in COSL

All the COSL's drilling rigs have the condition monitoring for critical equipment but do not have the remote support services using condition monitoring and online sensors. Levett(2006) stated that the potential for remote operations is significant for offshore platforms, but it is imperative to separate fact from fiction. The application of the remote support services can be evaluated from different considerations including:

- The platform features (such as work domestically or abroad, the current condition monitoring status etc.)
- Feasibility analysis including cost-effectiveness analysis
- Concept evaluation

Actually, in order to evaluate and assess the full impact of remote or integrated operations, it requires expertise and competence in economics, production optimization, operations and maintenance, safety and reliability, human factors and change management(Levett, 2006).

7.1 Investigations in COSL

The questionnaires are attached to the appendix A. 52% of the respondents is working onshore and 48% of them are working offshore. 92% have used different kinds of condition monitoring but only 10% of them know or ever used the remote condition monitoring. One of the questionnaires is showed in the figure 7-1.

After finish the questionnaire, please send to my e-mail: b.du@stud.uis.no , you can also invite your colleagues to join in this.

Name: *Song Jianfu* Position: *Electrical Enginer* Date: *2013/1/5*

Question 1: Do you work onshore or offshore?

A onshore B offshore

Question 2: Have you ever used condition monitoring for equipment predictive maintenance.

A Yes B No

If yes, please list the specific method:

Vibration test for the mud pump

Question 3 How about the remote support services using condition monitoring and online sensor data?

A Yes B No

If yes, please list the specific method using satellite or optic fiber or others

If no, please read the introduction of remote support services using condition monitoring or check it on the website: <http://diagsol.co.uk/products/service-solutions/>

Siemens use the PLC remote diagnosis system for trouble-shooting

Figure 7-1 the questionnaire for remote support services in COSL

But most of the respondents have showed great interest to the remote support services and realized the potential benefits which the remote support services would bring forth. The top four benefits are showed below:

- Instant access to real-time data without on-site survey
- Ability to maintain nominated production level by avoiding the deferment.
- Reduction of logistics costs which includes the helicopter and accommodation cost for avoidable offshore missions
- The utilization of domain experts and skilled personnel both offshore and onshore.

For the challenges, the top 3 challenges are:

- Key operational workflow management
- Life circle cost and initial and starting investment
- Technology integration.

7.2 The platform features

For the drilling rigs in the Bohai Bay, from Communications with equipment management director of production optimization department in COSL, the benefits of remote support services cannot offset the cost of the remote support services. The equipment director of COSL said that some portable condition monitoring equipment can be utilized by offshore maintenance team to make some predictive and preventive maintenance that is enough. But for the Iraq base, the service resources for some outsourcing maintenance are so limited and need quite longer time to access the base. So the planned maintenance and remote support & diagnosis can be done before the failure happens. But considering the challenges including the band width of internet connection, the real remote support services cannot realized, only some critical running parameters of the equipment can be transmitted to the equipment support center and make some maintenance plan in advance.

7.3 Investment analysis for the remote condition monitoring system application

The Iraq base of COSL has many challenges in the special condition with higher temperature and security problems. The services resources are limited and expensive, so most parts of the spare parts and services are from the mainland of China. So this means much more downtime because of waiting time and repair time. To reduce the impact, COSL made the equipment redundantly with backup systems, installed better diagnosed tools with laptop locally, signed guaranteed security transportation contracts and set up double spare parts stock initially.

However, there are also some problems which cannot be diagnosed without the experts from OEM or because the site engineers have less competence. So COSL is conducting an investigation and planning to use a remote condition monitoring system for the remote support. The new built equipment including the vehicle acidizing and coiled tubing equipment should install the condition monitoring sensors, industrial computers and software for prognostics and system analysis. The data can be transferred to China and then analyzed by domestic experts.

Schneider has developed a system for this kind of remote support services including both hardware and software. The theoretical design has been showed in the figure 7-2. The satellite internet bandwidth is 2M, so it is OK for the data and picture transmission.

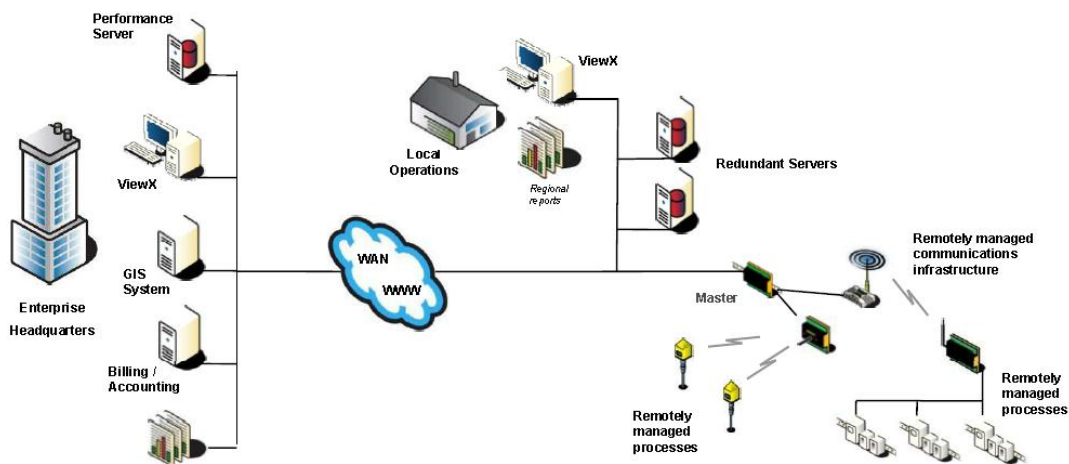


Figure 7-2 Remote support services using internet by satellite(Yin, 2013)

7.3.1 Initial investment for the condition monitoring system in Iraq

The initial investment for the added system is estimated to be 8.8 million RMB each year for the first two years showed in the table 7-1 (from the vendor’s quoted price but be adjusted by scale).

Table 7-1 the initial investment in the first two years (million RMB)

Item	The first year	The Second year
Investigation cost	0.5	0
Equipment cost (the first payment 70%)	7	0
Equipment cost (the second payment 30%)	0	3
Fabrication and installation and commissioning cost	1.3	5
Insurance and training cost	0	0.5
other CAPEX	0	0.3
Total costs	8.8	8.8

7.3.2 The spare parts and maintenance cost

The spare parts and maintenance cost can be estimated to be saved from 20million

RMB to 15million RMB each year. In 2012, the emergency procurement costs and repair costs were over 6 million RMB in Iraq base. From the remote condition monitoring system, the predictive and planning maintenance can reduce the emergency costs by 80%. So the estimated spare parts and maintenance cost is 5 million RMB which is a conservative number because the current stock level also can be optimized.

7.3.3 The operation revenue

The operation revenue can be increased from 60 million to 68 million because of the less downtime and higher production. COSL is an oilfield services company, most of the services fees are charged by day rate. In 2011-2012, the average lost services fees because of downtime are over 4 million RMB, and the workload (number of drilling and completion wells) are reduced by 6% which has 10 million RMB economical potential. So the estimated operation revenue has an 8 million RMB increase.

7.3.4 NPV comparison between with and without the system

Project life: 5 Years

Salvage value: 0 RMB

Discount rate 10%

Here is the NPV comparison between using the condition monitoring system (Table 7-2) and without the condition monitoring system (Table 7-3), the monetary unit is million RMB.

Table 7-1 The NPV of condition monitoring system (monetary unit: Million RMB)

investment	year1	year2	years 3	year4	year 5	year 6	year 7
revenues			72	72	72	72	72
spare parts cost			-15	-15	-15	-15	-15
fixed costs			-24	-24	-24	-24	-24
pretax profit			33	33	33	33	33
tax(tc=0.78)			25.74	25.74	25.74	26	25.74
net profit			7.26	7.26	7.26	7.3	7.26
initial cost	-8.8	-8.8					
NPV with system	7.47199						

Table 7-2 The NPV without condition monitoring system (monetary unit: Million RMB)

investment	year1	year2	years 3	year4	year 5	year 6	year 7
revenues			55	55	55	55	55
spare parts cost			-25	-25	-25	-25	-25
fixed costs			-24	-24	-24	-24	-24
pretax profit			6	6	6	6	6
tax(tc=0.78)			4.68	4.68	4.68	4.7	4.68
net profit			1.32	1.32	1.32	1.3	1.32
initial cost							
NPV without system	4.1354						

The assumption and estimated data here is not the real data because of company information security, but the specific number is made by the real rate. From the comparison, the NPV increase is not so obvious because the other cost is assumed to be the same which is a conservative figure for the calculations.

It is evident that the investment analysis benefits can be expected although the investment is higher for the monitoring system. We can get more from the decision tree in the figure 7-3.

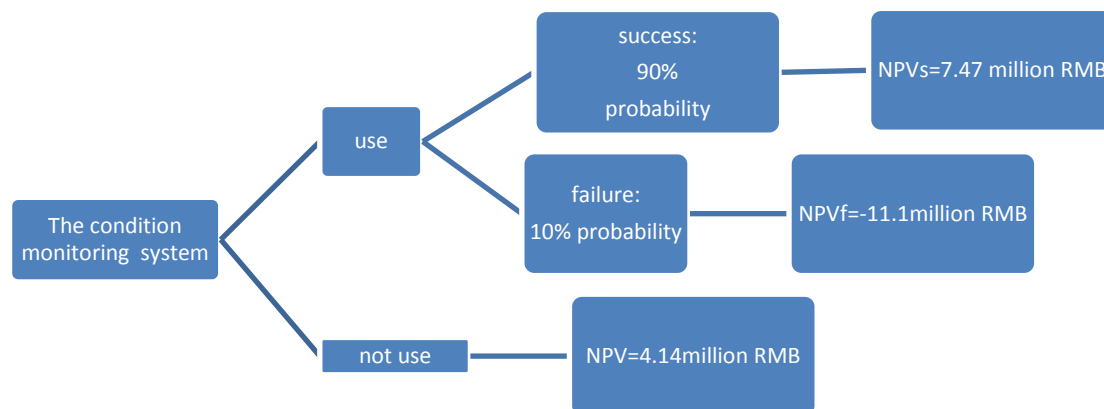


Figure 7-3 Decision tree for the condition monitoring system investment

So the expected payoff will be $7.47 \times 0.9 + (-11.1) \times 0.1 = 6.61$ Million RMB $>$ NPV(without the system). The reputation of COSL in operation and maintenance will attract more contracts in Iraq and Middle East market. So the system can be tried in Iraq base. The data and the calculations have some uncertainties which

can be offset by these indirect benefits including the reputation increase and sustainable development.

7.4 Conclusions

Based on the specific conditions of COSL, the potential benefits can be realized but COSL need a long way to go for the realization of the remote support especially e-maintenance and e-operation. But some small system can be tested to accumulate experience especially in abroad bases such as Iraq, Indonesia, etc.

8 Development trend of technology and management in condition monitoring and online sensor data communication

The current application of remote operations based on condition monitoring and online sensor data have three features:

- it has been applied to unmanned platforms, subsea equipments and satellite wells(Levett, 2006).
- Most of the application happened in the high production reservoirs and fields.
- The remote supports services limit on the equipment operations and maintenance.

So questions are brought forth and need further study:

- How to apply this in the manned platforms which may have some collision between on-site operation team and remote support centers?
- How to apply this in the limited production output wells which is not so cost-effective to build such a large system ?
- How to integrate the equipment, business and process automation?

8.1 Application of remote support services in the manned platforms

The Human Resources management should be well designed to make a good cooperation between on-site operation team and remote supports centers. They should have a detailed work scope and responsibilities for the system running. Besides this, if the added system can bring added value and offset the added cost decide by if it can:

- Increase the availability and reduce the downtime of equipment
- Reduce lost production

- Optimized field organization settings.
- Increased well production rates.
- Reduce operation cost including logistics, spare parts, on-site services etc.

8.2 Application of remote support services in some small production oilfield.

The challenges in the small production oilfield is really a barrier for the application. The field lifetime is so short and the production is small make it is not cost-effective to build the remote support system. How to make the system can be repeated used such as plug-in system is the study direction and develop trend. For example in the following figure 8-1. How to make our sensors and communication equipment can be easy installed and disassembled with a longer lifetime is the key value to the system. The wireless communication is really preferred from this side. In nowadays oil and gas industry, the rolling development model are used for production, which means some supplemental oilfields will be developed after the production decrease. In order to save cost and avoid repeated construction, the oil and gas are always transferred to the old platforms. Furthermore, these oilfields are not so far, so the low cost and flexible wireless communication are paid great attention.

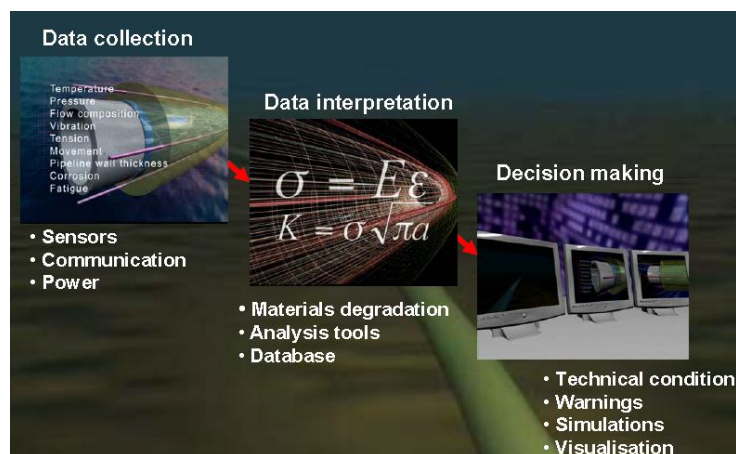


Figure 8-1 remote support services model using condition monitoring and online sensors(Knudsen, 2009)

8.3 The integration of equipment, business and process automation

“Integrated Production operations(IPO) can play a central role in exploiting by hydrocarbon reserves to their fullest extent and can also provide a fulcrum point about which to organize strategies and initiatives for the emerging Digital Oil Field of the Future.”(Reid et al., 2006). The automation will not only limit on the equipment operation and maintenance automation, but also business automation and process automation.

Advanced technology in ICT is changing our world and many systems for e-maintenance application has been designed(Benbelkacem et al., 2009). Holmberg(Holmberg et al., 2010) stated that E-maintenance is a future flexible, mobile and global solution towards improved cost-effectiveness, safety and sustainability in the modern society. Figure 8-2 showed the concept of e-maintenance.

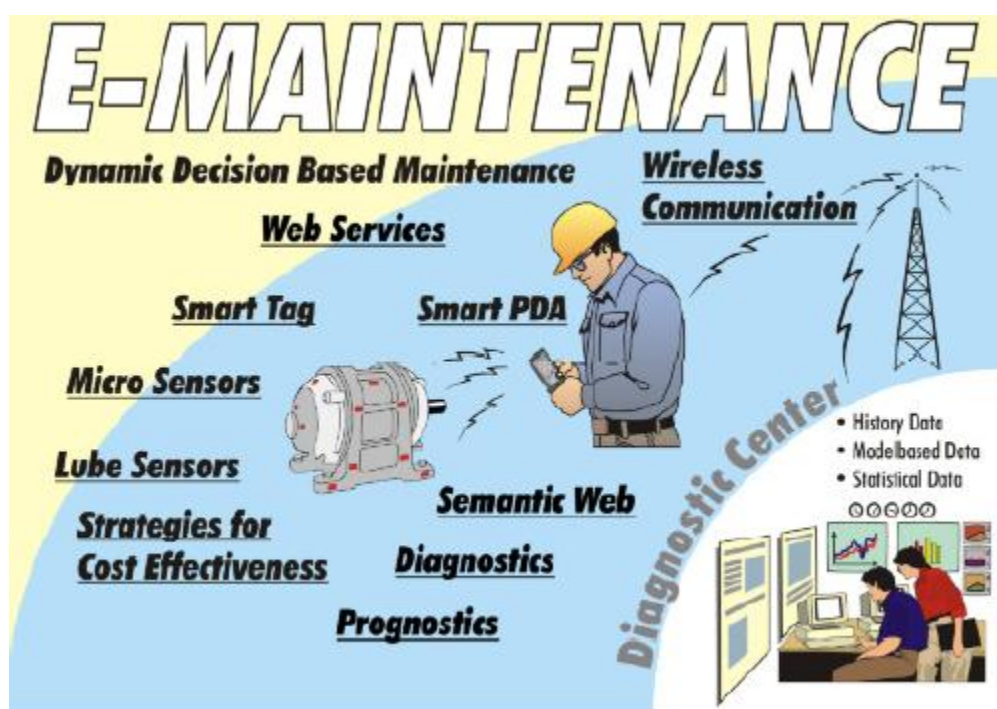


Figure 8-2 E-maintenance(Holmberg et al., 2010)

8.4 Conclusion

It has been possible for the remote support services application to make our plant in higher efficiency and reliability. The integration of technology and business process make the information shared by multidiscipline and the optimize decision will be

made. The remote support services such as e-maintenance, e-operations will make great profits and contributions to the industry.

9 Recommendations and further research

The state of art remote support services using condition monitoring and online sensors have influence maintenance technically and organizationally. However, facing the challenges, further research should be strengthened to make the operation and maintenance solutions increasingly convincing. The key performance indicators such as ultimate reservoir recovery, OPEX, field lifetime and lost production push the remote condition monitoring solutions to a higher performance. From the author's side, the further research mainly focuses on:

- **Enhance the reliability of the system**
The internet speed vary with the load and bandwidth, some problems such as time delay , data loss may happen, in the future work, some development in these areas will be started to make the remote support system in a real time with effective measures.
- **Increase precision in condition monitoring prognostics.**
The time and frequency of the condition monitoring can be optimized to save costs without increase downtime. With the development of high speed computer, the calculations and analysis on our database and equipment running parameters will be refreshed and dynamic to optimize our maintenance plan.
- **Sustainable and harmonious development**
The main objective of our work is to make our earth develop in a sustainable way and build a harmonious society. The further study should be paid more on the environmental conservation, energy saving and personnel safety. Human has made great progress in changing the world, how to make our earth more beautiful should be put in the top place not the GDP. The system design should consider more on the human factors, environmental & energy savings, safety and economics. For example, an advanced net-based operation and maintenance system with robots will make our work safer, more challenging and exciting.
- **Management level and organizational settings**
Technology cannot make our services effective without the good management and organizational settings. How to make the information collaboration, knowledge and e-intelligence collaboration well are mainly decided by the management level and organizational settings.
- **High efficiency in data management**

The data from different sensors are growing, the data are growing year by year, how to management these data and quick access to these data when we need them? If they are not well management, the action will be lower even make the wrong decision as the data are so miscellaneous.

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Appendix A: Questionnaire for remote support services

Questionnaire introduction:

My name is Du Baoli, working at Production Optimization Department of COSL. I'm currently doing my master's thesis, which deals with remote support services using condition monitoring and online sensor data. As a part of my thesis, I'm conducting a questionnaire that the possibility of application the services in COSL drilling platforms and other oilfield services. The aim of the questionnaire is to find the challenges and benefits of the application. I would really appreciate your participation and would share the final investigation results.

Contact information

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After finish the questionnaire, please send to my e-mail: b.du@stud.uis.no , you can also invite your colleagues to join in this.

Name: Position: Date:

Question 1: Do you work onshore or offshore?

A: onshore B offshore

Question 2: Have you ever used condition monitoring for equipment predictive maintenance.

A: Yes B No

If yes, please list the specific method:

Question 3 How about the remote support services using condition monitoring and online sensor data?

A: Yes B No

If yes, please list the specific method using satellite or optic fiber or others

If no, please read the introduction of remote support services using condition monitoring or check it on the website: <http://diagsol.co.uk/products/service-solutions/>

Question 4 Do you think which benefits is the most important for your department? Please choose the top 4 benefits.

- Instant access to real-time data without on-site survey
- Ability to maintain nominated production level by avoiding the deferment.
- Reduction of logistics costs which includes the helicopter and accommodation cost for avoidable offshore missions

- The utilization of domain experts and skilled personnel both offshore and onshore.
- The safety alerts and maintenance monitoring system can be implemented and will definitely improve safety of operations.
- Scarcity of knowledge engineers in E&P industries forced us to find a new way to better utilize the existing staffs as well as to build the young, less-experience ones. Collaboration over the telecommunication channels will help lessen this program.”(Senivongse et al., 2011).
- Predict the TTF(Time to Failure), make our mode of work become to pre-active (planned maintenance) without break down.
- Reduce the need of staff to attend the site in person work in danger zone.
- The other direct or indirect benefits, please list below :

Question 5: Do you think which challenges is the most important for your department?
Please choose the top 3 challenges.

- Key operational workflow management
- Decision making
- Life circle cost and initial and starting investment
- Technology integration
- Added work for some positions
- Large scale social and individual people impact
- The other direct or indirect benefits, please list below :

Question 6: Do you have any suggestions for remote support services in COSL and CNOOC?

Appendix-B Classification analysis of spare parts

Classification Based on Consumption:

“Another method of classifying spares is on the basis of **annual consumption value**. As it is true for any inventory situation, Pareto's principle can be applied to classify maintenance spares based on consumption value.”(Anonymous, 2012)

“**Pareto principle** : The significant items in a given group normally constitute a small portion of the total items in a group and the majority of the items in the total will, in aggregate, be of minor significance.”(Anonymous, 2012)

“This way of classification is known as ABC classification:

CLASS A: 10% of total spares contributing towards 70% of total consumption value.

CLASS B: 20% of total spares which account for about 20% of total consumption value.

CLASS C: 70% of total spares which account for only 10% of total consumption value.

In a specific spares control system, it is quite possible that in a single year, many spares would not have been consumed at all. In such cases, it is better to perform ABC analysis on longer consumption period data, say 3 years. Then only spares will not be left out in this classification.”(Anonymous, 2012)

Classification by a criticality:

V: vital

E: essential

D: desirable

Classification by frequency of demand:

F: Frequently used

S: Less used

N: rarely used