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Challenges of SAS (Safety Automation System) execution.

By

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Abstract

Extension of the production facilities life, focus on increased oil recovered, development of satellite reservoirs tied to the main facilities and innovation and advancement in the SAS technologies have led to an increased demands on the modifications and updating existing SAS and replacement of obsolete SAS technologies used on the production facilities.

The SAS has a significant role in the petroleum processes because the failures in SAS can pose serious hazards for people and the environment. The SAS helps to detect conditions that signal potentially hazardous disturbances, and assist the operators of the system in the control and elimination of those disturbances. Use of SAS in the petroleum industry provides better protection and control solutions, real time performance required to meet reliability demands, industrial productivity and energy efficiency. At the same time SAS system has to be regularly updated and modified to take into account various factors described earlier which might impact on the safety of process. The challenges of SAS project implementation are investigated in the current master thesis.

The main objective of this master thesis is to evaluate current SAS installations in the Norwegian Continental Shelf and its compliance with an industrial standards and regulations. Furthermore the thesis reviews development history of current SAS installations in NCS, evaluates possible future industrial demands and its impact on the future SAS technology, compares three SAS vendors which have current installation on the NCS and provides technical characteristics cross analysis of these systems.

In the last part, the numbers of proposals have been made for future SAS developments and innovations under industrial demands. Recommendations have been proposed for resolving of gaps and challenges of current SAS installations in NCS.

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And last but not the least thank to my husband for his support during my time-consuming studies process and special thanks to my mother for her support morally and spiritually. It has been challenging phase of my life!

Content

Abbreviations

AMS-Asset Management System

API- American Petroleum Institute

AS- Automation Systems

CAPEX-Capital Expenditures

CCF- Configurable Control Functions

CP- Communication Processor

CPU-Central Processor Unit

CSF-Control System Flow chart

DCS- Distributed Control System

DSA- Distributed System Architecture

ESD- Emergency Shut-Down System

F&G-Fire & Gas System

FBD-Functional Block Diagram

FTE- Fault Tolerant Ethernet

HI - High Integrity

HMI-Human Machine Interface

HVD- High Voltage Direct Current

HW- Hardware

IMS-Information Management System

IMS-Information Management System

I/O- Input/Output

ISO- International Organization for Standardization

LAD-Ladder Diagram

LCC- Life Cycle Cost

MTBF-Mean Time between Failures

NCS-Norwegian Continental Shelf

O&G- Oil and Gas

OLF-The Norwegian Oil Industry Association

OPEX-Operating Expenses

OS- Operator Systems

PCS-Process Control System

PDCS-Power Distribution Control System

PKS- Process Knowledge System

PLC-Programmable Logical controller

PSD-Process Shut-Down

SAS-Safety Automation System

SCADA- Supervisory Control and Data Acquisition

SCD- System Control Diagram

SFC-Sequential Function Chart

SIL- Safety Integrity Level

SIS- Safety Instrumented System

SRS -Safety Requirement Specifications

STL-Statement List

SW- Software

TCL- Taylor Control Language

TLL-Taylor Ladder Logic

WDM-Wireless Device Manager

EPC- Engineering Procurement Construction

Chapter 1

1. Introduction and background

1.1 Introduction

The Norwegian Continental Shelf is one of the biggest and most important offshore markets in the world. The oil and gas sector is important part of development in the Norwegian Continental Shelf. This industry applies the most innovative technologies new solutions and opportunities. "*In many ways, the Norwegian petroleum industry is an economic and technological fairy tale. In the course of a little more than 30 years Norway has developed a petroleum industry with world class products and solutions"*(Keilen, 2005) .The industrial demand and new technologies becoming advanced and more complex and provide the cost effective result with increasing production and reducing maintenance cost. Today, most process units are highly dependent on automated control systems and changes in the technology cause the changes in the automated control systems. The integration of new technology in the industrial process is very challenging process. Because the new technology implementation creates the new operational procedures, produces new products or services or rearranges the business plan and needs to be implemented into all affected parts of the organization.

Other affected area by technology development is safety. The new technology innovations from the simplest to the most complex require to keep them operating properly as it was designed. Today's technology developing faster than the standards can follow, but then the standards will dictate effectiveness and functionality as frameworks in the future. Standards are other force of industrial process modifications .The standards and requirements establish the frames and regulate safe technology functionality and technical performance. Safe functionality of industrial processes is the main focus in the Oil & Gas industry. The goal of offshore operations is zero harm and hazard and Norwegian Shelf has proven that production of oil and gas can be compatible with environmental considerations.

1.2 Project scope and objectives

The objectives of this master thesis are to identify possible challenges during the SAS project implementation. The goal is to present information about SAS installations in the NCS and to identify different approaches and solutions for the SAS installation. The thesis identifies the following questions:

- Which standards and regulations apply for the SAS development and implementation in the petroleum industry?
- Which are the main current SAS installations in the Norwegian Continental Shelf?
- Which are the main phases and challenges companies face during the SAS project implementation?
- Which are the future industrial demands for the automation companies?

The main contributions in the master thesis are:

- Identification and classification of standards and guidelines that company can use for the SAS project implementation.
- Identification of main technical automation systems characteristics installed today in the Norwegian Continental Shelf.
- Identification of challenges for the SAS implementation process in the Norwegian O&G industry
- Proposition of future industrial demand for the SAS development.

The master thesis provides insight into the application of selected SAS on the NCS in the Oil & Gas industry and provides suggestions to fix the gap existing in the company methodology. This knowledge might also be helpful during the SAS project development and implementation.

1.3 Methodology of data collecting and analysis

Literature studies in this master thesis has been collected and analysed from different sources. The information from companies’ brochures, web sources, journals and presentations, compendium for the subject MOM 410 Human-Technology-Organization by Jayantha P Liyange (UiS) and other academic literature from University of Stavanger, information collected through discussion with supervisors at the University of Stavanger and Apply Sørco and other literature as listed in references at the end.

1.4 Limitations

The objectives of this master thesis are not to find clear answers and solutions for challenges of SAS project implementation, but to evaluate current installation in the NCS and industrial demands for the SAS project implementation. The analysis is based on the public data and do not present any quantitative data from SAS manufacturer companies because of companies policy and confidentiality reasons. The master thesis will be limited to give qualitative analysis due to unavailability and complexity of data.

1.5 Structure of the project

The structure of the project includes six chapters with following content:

Chapter 1 This chapter describes the purposes and scope of the work, introduces the questions which are going to be discussed in the master thesis, mentions about limitations and data collecting method during investigation and analysis of the topic.

Chapter 2 This chapter presents general definitions related to the master thesis for better understanding of topic and prerequisites for the challenges of SAS project implementation. The chapter presents the main phases of the SAS project implementation and project cost analysis.

Chapter 3 This chapter presents cross analysis of SAS installations on the NCS by comparing of three SAS vendor companies product, technical characteristics, their operational features and their current users in the NCS.

Chapter 4 This chapter describes the challenges of SAS project implementation, factors and conditions which change the methodology of SAS vendor companies under new industrial developments and demands.

Chapter 5 This chapter presents possible prognoses for the future industrial demands and requirements and provides several propositions for the future SAS development. It is also provides some recommendations for the improvements of SAS installations on the NCS.

Chapter 6 This chapter evaluates and interprets the result of the project, comments the possible errors which have been done during the project implementation and discuss possible future study of the problem.

Chapter 7 This chapter gives a brief summary of the results in the thesis and where these results could be used.

Chapter 8 This chapter provides the references to the source used during the work.

Chapter 2

2. SAS theory and basic definitions

2.1 SAS common definitions

SAS has a major role in the operation and control of industrial processes. SAS is designed to perform monitoring, operation and supervisory control, data computation and operational analysis of the process.

The conceptual SAS topology is refers to the Appendix 3-1. SAS includes not only hardware and software components of control system but also includes the computer systems, network system components, hardware and software interfaces, communication devices and protocols and smart operation tools. The SAS establishes secure industrial control and includes supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), Integrated Control and Safety System (ICSS) and other control system configurations.

Some of the common definitions listed in the (table 2-1) below might be useful for the understanding of different SAS configurations.

Table 2-1. Basic definitions

SCADA	Supervisory Control and Data Acquisition is used for process control, the gathering of data in real time from remote locations in order to control equipment and conditions. SCADA is used more often for utility area control in the oil and gas industry. SCADA systems include hardware and software components. The hardware gathers and feeds data into a computer that has SCADA software installed. SCADA warns when conditions become hazardous by sounding alarms.
DCS	Distributed Control Systems are generally used to control huge production area with I/O's ranging from 10,000 to 30,000 I/O points. It includes its own controllers, communication components, chassis and human interface.
ICSS or SAS	Integrated Control and Safety Systems provides control and includes DCS, ESD, F&G, PSD systems .Operator may quickly determine the state of the plant and provide the necessary manipulations to ensure that optimum

	operations and maximum safety are achieved.
Integrated Operations (IO)	Integrated Operations is challenges of having personnel, suppliers and systems offshore, onshore and in different countries. Integrated Operations involves using real-time data and new technology to remove the divides between disciplines ,to makes operations and asset management more efficient through the integration of data and models, and utilizing the powers of cross-disciplinary teamwork and work processes
Smart Operations	Smart Operations is operations dedicated to help with organizational behaviour problems, manufacturing, distribution, quality control or customer service .Smart Operations consist of a set of tools and available management applications to simplify deployment, management, and troubleshooting of industrial issues.

2.2 Analysis of Safety Automation System changes in NCS.

The extensive process of industry changes in relation to major technological, operational and organisational changes has effect on safety environments. In 2001 – 2002 a new framework has been issued which demands that the responsible part shall promote a good HSE-culture and keep responsibility for their behaviour (Thraldsen , 2011) .

Today, the industry focuses first and foremost on improving the safety standards and cost reduction by applying innovative technology design and SAS deployment and modifications .One of the SAS modifications is unification of system. The SAS has been evolved separately over the last 20 years. In earlier development stages SAS was developed by different manufactures with similar technologies, however with different operation interfaces. This was very inconvenient and caused many human factor mistakes. It forced petroleum industry to move towards better coordination and operations with developing new reference parameters under the common control philosophy of Safety and Automation System and Human machine interfaces.

Another SAS modification towards safe operations and conditions was development of smart operations tools in order to reinforce observations of unsafe practices or conditions, predict them or prevent if possible. Detailed analysis of smart operations provided in chapter 4.

Significantly changed the way of SAS design and implementation because of industrial demands and practices require new standards of design with new approach to implementation. The SAS design and implementation phase should go through safety analysis with focusing on the automatic analysis of product design to derive safety properties.

The SAS has to be reliable and safe since failure in SAS system might cause loss of human life or damages to environment. Development of SAS must comply with certain standards or guidelines and prioritise the safety operations requirements.

2.3 Standards and regulations used for the SAS design and implementation

The SAS design solutions and implementations processes are controlled by organizations of petroleum authority, organizations of standards and regulations and other dedicated organs.

The standards and regulations have to be applied during the SAS design; implementation and execution to ensure adequate safety, consistency and lifecycle effectiveness for all parties involved in the process developments. The standards are defined as "*document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context*" (ISO/IEC, 2004)

The focus of this chapter is identification of standards which are used for the SAS projects development and implementation in the Norwegian Continental Shelf.
The list of standards and guidelines are presented in the (table 2-2) below which are the most relevant for the Instrumentation & Automation design and implementation. Any changes and modifications in the standards and regulations have to be implemented and tested during runtime process.

Table 2-2. Standards and guidelines used for the Instrumentation & Automation design and implementation

Standards and Regulations	Standards functionalities
IEC 61511 "*Functional safety-Safety instrumented systems for the process industry sector*"	Standard gives requirements to instrumented safety functions .Standard instructs regarding safety barriers, SIL, failure probabilities, HW fault, tolerance and complexity of the systems components. This standard is used for the safety level identification during the safety system development.
IEC 61508 "*Functional safety of electrical/electronic/programmable electronic safety related systems*"	Standard used as basis for specification, design and operation of Safety Instrumented System (SIS).Standard covers requirements for safety-related HW/SW developing. Provides presentation of the safety life cycle.
OLF 070 "*Recommended guidelines for the application of IEC 61508 and IEC61511 in the petroleum activities on the Norwegian continental shelf***"**	Guidelines adapt IEC 61508 and IEC 61511 standards for use in the Norwegian petroleum industry. Guidelines instruct that activities necessary to ensure that the SIL requirements are identified designed and maintained during lifecycle of the systems.
NORSOK I-001 "*Field Instrumentation"*	The NORSOK standards are industry standards developed by the Norwegian petroleum industry. The NORSOK standards refer to the recognized regional, national and international standards and add some value for the petroleum industry developments and operations. This NORSOK I-001 defines requirements to the field instrumentation design including installation specification, engineering units for the field device, and main types of measuring field device characteristics. This standard used for development of the first SAS architectural level.
NORSOK I-002" *Safety and automation system (SAS)"*	The NORSOK standard based on recognised international standards such as ISO 10418 etc. NORSOK I-002 defines the SAS as the overall Safety and Automation System which controls equipment and has integral concept of process control either from one vendor or acquired from several sources. NORSOK standard has general overview of system topology and gives the general regulations and requirements for the SAS implementation.

NORSOK I-005 *" System Control Diagram (SCD)"*	The NORSOK standard provides specification for the system functional behaviour and interconnections. The standard regulates the concept of control logic in order to cover all possible process aspects and eliminate missing functionality or links. The standard concept is to provide SCD that combines functional design requirements, complex control functionality, and interconnections between the systems, interlocking and safeguarding logic in order to unify the process operation logic. This standard is applied during SAS software design.
NORSOK Z-010 *"Electrical, Instrumentation & telecommunication Installation"*	The standard regulates installation functionality and technical requirement for the electrical, instrumentation and telecommunication equipment. This standard also provides marking and labeling philosophy for the electrical equipment, grounding, and cabling installation standards, junction box installation and materials. The standard used during design phase for the field architectural level and design of telecommunication devices.
NORSOK S-001 *"Technical Safety"*	"This NORSOK standard describes the principles and requirements for development of the safety design of offshore installations"(NORSOK S-001).This NORSOK standard in conjunction with other international standards such as ISO 13702 etc. defines the requirements for the technical safety design, implementation in the different process areas, safety barriers installation, and Emergency Shut Down principle hierarchy and alarm functionality.
ANSI/IEEE 1008 "*Software Unit Testing"*	The standards developed to assist unit tester and unit test supervisor with software engineering concept and testing approach. This standard describes a testing process, activities and minimum set of tasks for each activity and test evaluation result. This standard is used during implementation of SAS. All SW and HW designed onshore should be tested prior shipment to offshore.
API RP 551 "*Process Measurement Instrumentation"*	The standard defines requirements for design and selection of system measurement, which has its own requirements. The standard, also defines the measuring device implementation and commissioning. This standard is used for the design of instrumentation level during the SAS development process.

API RP 554 "*Process Control Systems"*	The standard defines requirements for the process control system implementation, the basic functions of control system and recommended methodologies for determining the functional and integration requirements for a particular application. The standard defines practices to select and design the installation for hardware and software, project organization and management requirements .The second edition of API RP 554 cover instrumentation and control system general industrial process control topics.
API RP 557 "*Guide to Advanced Control Systems"*	This standard provides practices for the project identification, justification, management, implementation and maintenance of the control systems. The standard provides guidelines for defining work process and common functions for maintain the control system.
API RP 14C "*Analysis, Design, Installation and Testing of Basis Surface Safety System on Offshore Production Platforms*"	The standard presents recommendations for design, installation and testing of safety systems in order to protect any process components. The standard defines safety system overview, safety device symbols, and shutdown logic and safety levels analysis.
ISO 10418 "Petroleum and natural gas industry-Offshore production installation-Basic surface process safety system"	ISO is the most known standardization organization. The standard used for regulations regarding safety device design, location and installation. This standard could be used in conjunction with API standard API RP14C. The standard applied for the safety system design, safety level and safety barrier identification.
DNV OS-D202 " Instrument, control and safety systems"	This standard defines requirements for the design material, fabrications, installation, testing, commissioning, operation and maintenance, demolishing of the safety automation and telecommunication system. Example one of the standard requirements SAS level independence: "failure in one of the system shall not give failure for the remaining parts of the system. Even if all parts of automation system are integrated in one distributed system, safeguarding commands still has to be limited between the levels" (DNV Standard, 2013).
DNV-OS-A101 *"Safety principles and arrangements"*	"This is internationally acceptable standard of safety for offshore units and installations by defining requirements for design loads, arrangements, area classification, shut down logic, alarms and escape or communication"(DNV-OS-A101).The standard guidelines ,safety specifications and requirements for designers, suppliers, purchasers and regulators.

ISA 5.2 *"Binary Logic Diagrams for Process Operations"*	The standard provides logic diagram for the startup operations, alarm, interlocking in order to facilitate understanding of binary logic operations ISA 5.2 is a standard that provides symbols for standard PLC functional blocks such as AND, OR and NOT operators, SR flip-flop etc.
ISA 5.3 *"Graphic Symbols for Distributed Control/Shares Display Instrumentation, Computer Systems"*	The standard defines symbolism and rules usage for the control system diagrams, HMI and alarm specifications. The standard also provides flow diagram, process and mechanical diagrams and widely applied for the SAS HMI design.
ISA S5.4 *"Instrument Loop Diagrams"*	This standard provides minimum information for a loop diagram. The information regarding instrument loop is typically part of an engineering drawings. The standard mostly provides guideline for the preparation and use of instrument loop.
ISA S5.5 *"Graphic Symbols for Process Displays"*	The standard defines requirements for the user display that are used offshore for the process monitoring and control. The standard graphical requirements shall corresponds and visualise the process equipment. The standard defines the symbols and colour coding philosophy for the HMI. The unifying of operators displays decrease the needs for the trainings.
ISA 18.*2 "Management of Alarm Systems for the Process Industries"*	The standard provides alarm philosophy and alarm specifications, operator response to the alarm, colour coding and functionality. The standard provides alarm management lifecycle for the operations in the petroleum field.
ISA 50.02-2 "*Fieldbus Standard for Use in Industrial Control Systems, Part 2: Physical Layer Specification and Service Definition"*	The standard provides requirements for the Field bus installation, sizing and distance bases, material, environment arrangements, segments philosophy in the loop and other Field bus engineering guidelines.
ISA 99.02.01 *"Security for Industrial Automation and Control Systems: Establishing an Industrial Automation and Control Systems Security Program"*	"The standards describes the elements necessary to establish security management system (CSMS) for industrial automation and control systems (IACS) and provides guidance regarding development of those elements "(ISA 99.02.01)

Sometimes projects might have individual system solutions with specific standards per company requirements. In this case company still keep the common philosophy for system design.

2.4 Phases of SAS project in the Oil and Gas industry

The main challenges in the SAS project implementation is evaluation of SAS life cycle time. System life cycle evaluation begins with an engineering concept and end with decommissioning of the system (Stanley and Koy, 2007).

System life cycle goes through all possible phases and includes not only the life time of the plant from commissioning to dismantling, but also includes the time between possible production lines and planned maintenance (Zvei Automation group, 2012).

The main stages of SAS life cycle analysis for the oil and gas project refer to (figure2-1).

Figure 2-1. The SaaS Development Lifecycle (Kommalapati and Zack, 2011)

The Life Cycle stages includes all possible activities during project's development, production and decommissioning phases refer to the (table 2-3) below.

Table 2-3. SAS lifecycle phases

SAS Life cycle	Activities
Planning	Concept evaluation Resource analysing Tecnology selection analysis
Analysis	Resource validation

	Cost analysis
Design and Development	Technlogy selection Preliminary design validation Risk analysis Cost approval
Implementation	SW programming HW solution implementation and testing
Testing	SAS internal manufacturer testing
Acceptance	SAS Factory Acceptance Testing SAS shipment and delivery to end user. SAS Site acceptance test SAS Commissioning
Maintenance and Deployment	SAS support and operation SAS spare part support SAS modification after process preventive & corrective maintenance activity. SAS upgrade and modification Employee training and development support
Decommissioning	Dicommissioning and dismantling schedule and cost planning SAS Demolition Waste disposal

Today's companies plan their expectations and analyse possible risks along the way by using Life Cycle Time (LCT) analysis. Project development, investments and the return time of the investments are the most critical steps in the project life cycle for the project success. During the LCT planning different aspects have to be taken into account such as:

- Function-related properties:

Evaluation of system life cycle allows planning maintenance activities and in-time supply of spare parts what is important in terms of system safety. The main requirements of the user are focused on the safety and reliability of the system. Analytical methods for evaluation of risk analysis during the SAS lifecycle give impressive value of system reliability maintainability and functional safety.

- Device-related properties:

Process equipment has many variations of design options, performance, installation, foundation and support requirements, different mean-time between failures and spare parts. All possible parameters regarding equipment reliability, operations and spare parts have to be analysed during the design phase. End users company measure reliability of the product by problem-free operation therefor suppliers of products have to analyse failures over a time interval or other words Mean Time between Failure (MTBF). MTBF is a basic reliability analysis of system failure modes.

- Location-related properties:

The environment conditions have significant role in the life time of SAS installation. As an example of location effect on the SAS development is Statoil's and its partners oil field Skrugard and Havis in the Barents Sea outside Honningsvåg in Finnmark .The field is considered to be a prospective area and scheduled to come on stream in 2018.The challenges related to SAS lifecycle are :

- Arctic condition, that significantly reduce the life time of equipment and requires more often maintenance and more spare parts.
- Luck of infrastructure, that cause problem with spare parts storage.
- Long distance to the shore, that affects communication process, limited access to the specialist, extra cost for the transportation.
- Long distance to the market creates extra cost for the product transportation.

All these factors significantly affect LCT calculation result. (Markeset and Barabadi, 2011)

- Decommissioning and dismantling properties:

The obsolete phase of the process equipment and each component of the system have to be analysed and planned for decommissioning. The SAS lifecycle depends on the life-cycle of components or innovation cycle. The life time of the oil field itself usually between 15 and 40 years, however automation manufacturers normally have changes or modifications during this period in order to meet new requirements and regulations in the oil and gas industry. The new developments in the networking and web technologies also require changes of the system components such as upgrade of virus scanners or automatic updates, software components upgrades etc. The work lengths of life cycle components could be significantly different between the components refer to the (figure 2-2).

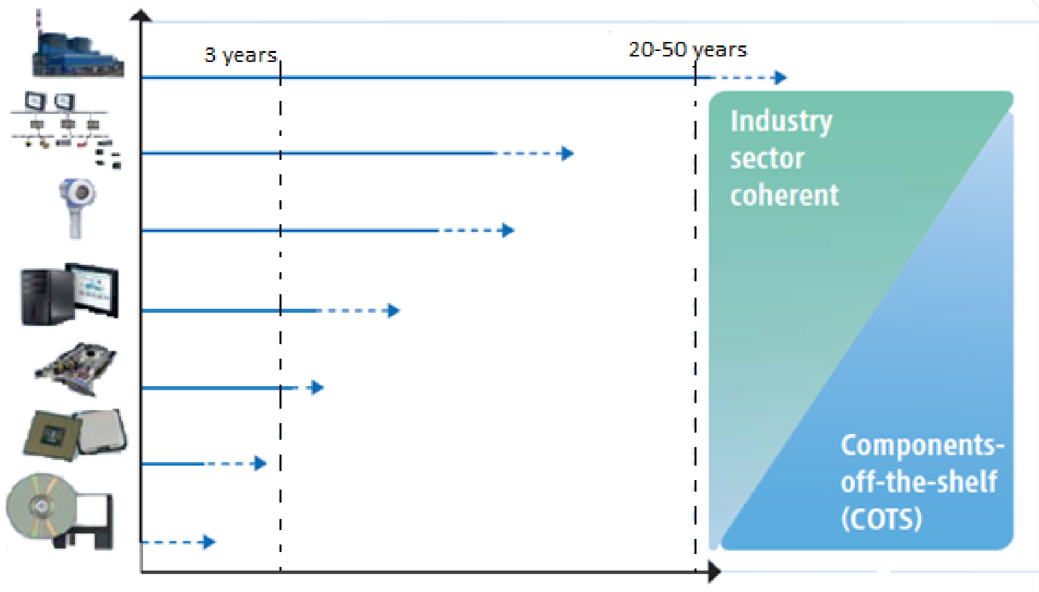


Figure 2-2. Life cycle overview (Zvei Automation group,2012).

The SAS Life cycle goes through all stages from the concept study all the way to demolishing. The SAS Life Cycle planning based on the previous development experience and lessons learned. SAS design should refer to previous activities that applied similar to those design phases, but focusing on a specific components and functionality of the system.

As it was mentioned above, companies are focus on increasing the safety and reducing the cost of the project. The cost analysis is playing significant value in the choice of the SAS project implementation.

2.4.1 SAS Life Cycle Cost

The Life Cycle Cost (LCC) analysis is an optimization technique from technical and economic prospects. The goal of LCC is to identify and choose the alternative solution that gives to the companies the lowest cost with the highest revenue over the lifetime. (Fabrycky and Blanchard, 1991).The LCC analysis used by company for comparison alternative technical solutions, alternative equipment, alternative system configuration, operational and maintenance concepts across alternative cost and life-cycle profit (Markeset and Kumar, 2000).The companies apply LCC calculation as part of the standard procedures during study phase of the project and LCC calculation gives the decision based for selection the best technical and economical solution. The LCC could be divided in the three main stages refer to (Langdon, 2007):

- Pre-Installation & Installations stage
- Operation, Maintenance & Replacement or Refurbishment stage
- Demolition or Disposal stage

In the each of these stages there are different critical and major cost drives for the company.   It is difficult to estimate all the associated cost due to the uncertainties which could happens during the project life cycle time. The maintenance cost often reaches up to 75 % of the total life-cycle cost of the system (Blanchard and Verma, 1995). In order to decrease the numbers of uncertainties connected to maintenance cost such parameters as equipment reliability and robustness have to be evaluated. The most effective approach to equipment life cycle evaluation is to appropriately integrate it into the design process. Reliability plays an important role in selection of equipment for lowest long term cost of ownership. LCC analysis helps to justify equipment and process selection based on total costs rather than the initial purchase price as the cost of installation, operation, maintenance, and disposal costs could exceed the equipment costs, many times over. (Barringer,1997)

Even if most possible cost drivers were included in the calculation of LCC it is still does not provides total cost of the project. "*A life cycle cost estimate does not provide the exact figure for the system costs, it merely gives an insight into the major cost factors and it may also help to compare alternative solutions. It highlights the magnitude of the costs and identifies areas for potential cost savings as well as areas for technical and organisational improvements*" (RTO publication, 2009)

LCC data is playing major role in the choice of system provider. Companies make a decision by selecting the alternatives offers the lowest total costs over time, including the planning, construction, set up, operation and dismantling of the system. Life Cycle Cost could be evaluated with help of standards and requirements listed below:

- DIN EN 60300-3-3 Dependability management – Part 3-3: Application Guide – Life Cycle Costing
- VDI 2884 – Purchase, operating, and maintenance of production equipment using Life Cycle Costing (LCC)
- VDMA 34160:2006-06 Forecasting model for lifecycle costs of machines and plants

Life Cycle Cost is significant topic between end users and manufacturers because:

- LCC provides users with better insight of the costs and points to the key cost drivers for potential cost savings.
- Provides a planning programme and budgeting
- Provides the logistic scenarios and provisions (spare parts, maintenance scenario etc.)
- Provides data for evaluation more different solutions (North Atlantic Treaty Organisation, 2009).

The SAS manufacturers have special programs for LCC calculation. For example ABB use *Sentinel Life Cycle Management Program*. This application predict annual fee for the maintenance cost and provides full monitoring offshore installed system, upgrades the system with necessary applications , antivirus ,licence and significantly reduce the cost of life cycle maintenance .(ABB publications, 2013)

The Siemens has *ISCM- Integrated Substation Condition Monitoring* which simulates expected performance and probability of risks in dependence of today's decisions. The ISCM reduces CAPEX and OPEX and plans relevant technical and economical solution. (Michler, 2013)

Chapter 3

3. Analysis of Safety Automation Systems in Norway

3.1 Introduction to the SAS manufacturer in Norway

The following sections present information and analysis of the most used vendors in the NCS. This information is not concerned with the profit margin but rather with purchased units and services. This chapter presents the SAS manufacturer cross analysis of technical, operational and functional characteristics of the product, development history, future technology and innovations.

Vendor market in Norway mainly shared among:

- Siemens AS Norway
- ABB AS Norway
- Kongsberg
- Honeywell Norway

Automation companies continuously develop and modify their products and services. These developments are stimulated by different industrial factors and practices, conditions and demands. Companies have different phases for products development through different life cycle phases. The next section demonstrates the SAS manufacturer products development and modifications history.

3.2 SAS vendor companies product development history

This chapter presents the SAS product development history which was demanded by modifications in the standards, regulations and industrial changes in technology and safety requirements. In the end of the each chapter presented approximate obsolete phase for the company products.

3.2.1 Siemens

Siemens is a worldwide automation company based in Germany. Their operations are mostly focused on the European market even though, they has presence worldwide. One of the Siemens business areas (Energy) provides automation technology, service and support in the NCS.
In the 1980 Siemens introduced TELEPERM control system for autonomous operations with local communication or for network operation with central communication. System became obsolete in

1999 because no longer replies to current requirements regarding the display and user guidance and regarding openness towards Manufacturing Execution System.
Next step in the Siemens automation system development was SIMATIC S5 for simple and economical solutions. This system was substituted by SIMATIC S7 however S5 is still in reliable service today and is being used on many installations. The end up date for the S5 is scheduled for 2015. The SIMATIC S5 controller was migrated to SIMATIC S 7 due to rapid technological changes and today's standards and regulations set new requirements on the automation system. One of the requirements for example is possibility to perform modernization and optimization of production plant while keeping production running.
Today SIMATIC S7 is migrating to SIMATIC PCS 7, but S7 is still in reliable service.
Technical framework of SIMATIC PCS 7 will be analysed in the later chapter together with the cross analysis of current SAS installation in Norway.
Table 3-1 below presents technical characteristic of the SAS provided by Siemens since 1980.

Table 3-1. Siemens products development history

Technical Characteristics	TELEPERM M	S-5	S-7
CPU Memory Size	32 KB working memory, can have 4 MB of data stored in its data storage area	CPU 941-2Kbytes CPU942-10 Kbytes CPU943-48 Kbytes CPU944-96 Kbytes working memory, can have 4 MB of data stored in its data storage area	S7-S300 128 KB working memory, can have 4 MB of data stored in its data storage area S7-S400 2,8 MB working memory, can have 8 MB of data stored in its data storage area
Programming language	Function blocks with TML programming or STEP M programming language.	Step 5 with different methods of representation (STL,CSF,LAD,GRAF 5/II for sequential control)	Programming languages STEP 7 with different method of representation: LAD, FBD, SFC, STL.

Communication Protocols	Communicates via CS 275 plant bus. Up to 20 m distances (local bus) or 4 km (remote bus). Up to 9 participants can be interconnected via the 20-m local bus.	Point-to-point connection with the CP 524 and CP 525 Local area network communications via the SINEC L1 network •Industrial Ethernet • PROFIBUS	SIMATIC S7systems communicates via Industrial Ethernet and point to point communication Field level of communication : Profibus, Profinet
Architectural Levels	Has three levels: HMI Level Control level Field level	Has three levels: HMI Level Control level Field level	Has three levels: HMI Level Control level Field level
Max. I/O modules	91 I/O modules	Digital module with 8/16/32 inputs each. Analog module with 4/8/16 inputs each.	Up to 1024 I/O 8 to 64 digital ch. 2 to 8 analog channels
Expansion Capabilities	Could be increase by additional use of extension system ES 100 K: 114 I/O modules	Expansion unit S5 - 115U and distributed I/O can be connected	Extension unit ET 200M I/O system can be connected.
O.S.	PC-based automation with Windows operational system.	PC-based automation with Windows operational system.	PC-based automation with Windows operational system.

Approximate evolution history could be proposed for development of Siemens automation systems and their obsolete phases refer to the (table 3-2) below.

Table 3-2. Siemens SAS evolution

Where :
New development
Maturity
Obsolescence

3.2.2 ABB

ABB is worldwide company and one of the main manufacturers of SAS installed in the NCS.

In 1984 ABB introduced MOD 300 controller.

In 1992 the MOD 300 system began its evolution to Advant with MOD 300 Software Distributed Control System (DCS).

In 2003 ABB introduced S800xA Distributed Control System (DCS). System 800xA is the latest installation of ABB's automation system and its technical characteristics will be analyses later in this chapter. The technical characteristics provided by ABB from 1984 years refer to the (table3-3).

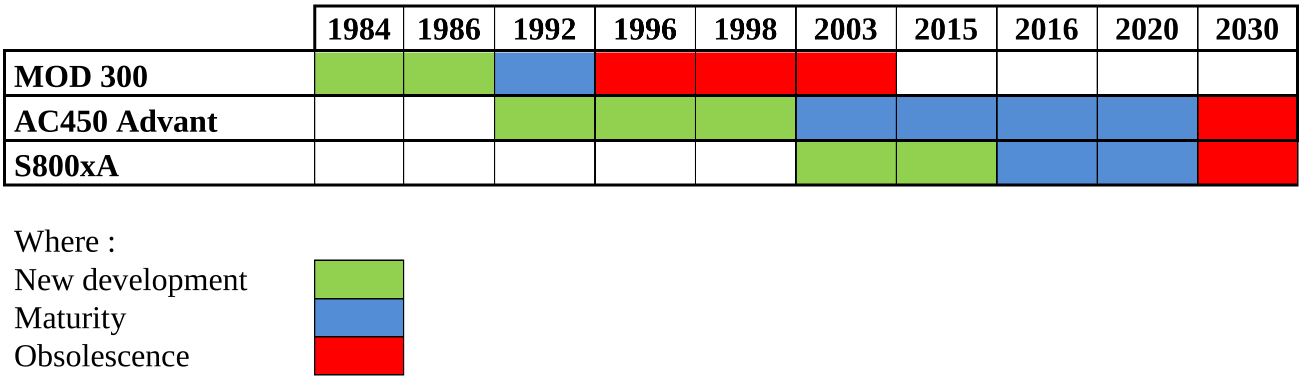
Table 3-3.ABB product development history

Technical Characteristics	MOD 300	Advant
CPU Memory Size	Flash memory 128 Kb	Flash memory 2/4/10Mb
Programming language	CCF, TCL,TLL,	CCF, TCL,TLL
Communication Protocols	MasterBus 200,Serial 1,5 Mbit,Twisted Pair	MasterBus 300,Ethernet 10Mbit
Architectural Levels	6 layers: Operating interface Engineering tools Communication network ControllersI/O's and power Remote I/O and drives	6 layers: Operating interface Engineering tools Communication network ControllersI/O's and power Remote I/O and drives

Max. I/O modules	Analog IO modules:4/8/16/32 ch.Digital IO modules: 16/32 ch.	Analog IO modules: 4/8/16/32 ch. Digital IO modules: 16/32 ch.
Expansion Capabilities	The communication board CI856 supports up to 5 S100 I/O racks.	The communication board CI856 supports up to 5 S100 I/O racks.
O.S.	Windows-based	Windows-based

Approximate evolution history could be proposed for development of ABB automation systems and their obsolete phases refer to the (table 3-4) below.

Table 3-4. ABB SAS evolution



3.2.3 Kongsberg

Kongsberg is the third well known provider of Automation system in Norway; unfortunately it was not enough technical information provided by Kongsberg in their public source and in cooperation with company was denied.

Kongsberg provides: The “K-pro” Process automation system with possibility to expand the number of IO by additional I/O module connection. For the K-pro system Kongsberg provide K-IMS for device data access.

For the safety processes Kongsberg provides “K-*Safe*” system which is used for Emergency shutdown (ESD), Fire & Gas detection and protection systems (F&G) and Process shutdown (PSD). The K-Safe system is designed and certified in compliance with IEC 61508 standard. Applications for the safety have SIL 1 to 3 levels. The system is redundant and has function monitoring of field sensors and actuators and has Safety Management (SSM) system, which is designed for crisis management on cruise ships and other complex installations. The SSM system detects and gives the operator a picture of the hazardous situation.

Kongsberg provides Marine automation system K-Chief 600.This system mainly consist of:

- Operator Stations.
- Watch Calling System for HMI. System provide alarm, trends
- Distributed Processing Units for process control.
- Dual redundant process bus and network: LAN or Ethernet technology.

Information is available from their website (Kongsberg Maritime, 2014).

3.2.4 Honeywell

The SAS provided by Honeywell has been chosen in spite the system is very new on the Norwegian market otherwise this system is well known worldwide and has a good potential to compete with other well-known automation systems in the NCS.

In 1975 Honeywell entered into a technical market with first Distributed Control System TDC 2000. The TDC-2000 had lack of discrete-event handling capability and the use of two separate operator interfaces (one for the supervisory computer and another for the basic controllers).

In 1987 company introduced next DCS TDC-3000, which is subsumed TDC 2000.

The Honeywell’s latest evolution is Experion PKS. The Honeywell TDC 3000 and Experion PKS DCS systems currently have been using in the oil and gas industry. The Experion PKS system first introduced in 2002 and since that time went through modifications and upgrades. Technical characteristic of the Experion PKS system will be analysed in this chapter later.

The technical characteristics of system development history presented in the (table3-5) below.

Table 3-5. Honeywell's System development history

Technical Characteristics	TDC-2000	TDC-3000
CPU Memory Size	4Mb system memory and 2Mb data memory	4Mb system memory and 2Mb data memory
Programming language	support sequence capability using SOPL Sequence-Oriented Programming Language	LAD/SFC/STL language options.
Communication Protocols	Data Hiway communication at 250 kb/sec	Local Control Network (LCN) communication at 5Mb/sec Open communication with ext. Systems via Ethernet,fiber optic 100Mbps
Architectural Levels	3 layers: Operational level(HMI) Control network level Controllers and I/O	3 layers: Operational level(HMI) Control network level Controllers and I/O
Max. I/O modules	TDC 2000 contains eight screw-terminal strips configurable as analog or digital inputs or outputs. Max. number: 16 AI ;8AO;32DI;16DO	TDC 3000 contains eight screw-terminal strips configurable as analog or digital inputs or outputs. Max. number: 16 AI ;8AO;32DI;16DO
Expansion Capabilities	TDC 2000 could have extended I/O	TDC 3000 could have extended I/O
O.S.	Enhenced Operator Station III communicate via Data Hiway	Enhenced Operator Station III communicate via Data Hiway

Approximate evolution history could be proposed for development of Honeywell automation systems and their obsolete phases refer to the (table 3-6) below.

Table 3-6. Honeywell SAS evolution

	1974	1986	1987	1996	1998	2002	2015	2016	2020	2040
TDC2000										
TDC3000										
Experion PKS										

Where :
New development
Maturity
Obsolescence

3.3 Operational characteristics of SAS installations in NCS

The number, the variety, and complexity of SAS for industrial process automation continue to grow, and the automation system components determines how rapidly and cost effectively SAS could be developed, implemented, and maintained. The SAS technical parameters imply through functions and features support of the system and they must be specified. A major theme for the SAS development is system architecture and communication to devises and components of the system. The system architecture often dictates the choice of components and determines system performance features such as reliability, capability, scalability, and cost.

3.3.1 Siemens

The current Siemens SAS is SIMATIC PCS 7. This system is continuously modifying due to the standards and regulations improvements and technology modifications. The SIMATIC PCS 7 general configuration refers to the (figure3-1) below.

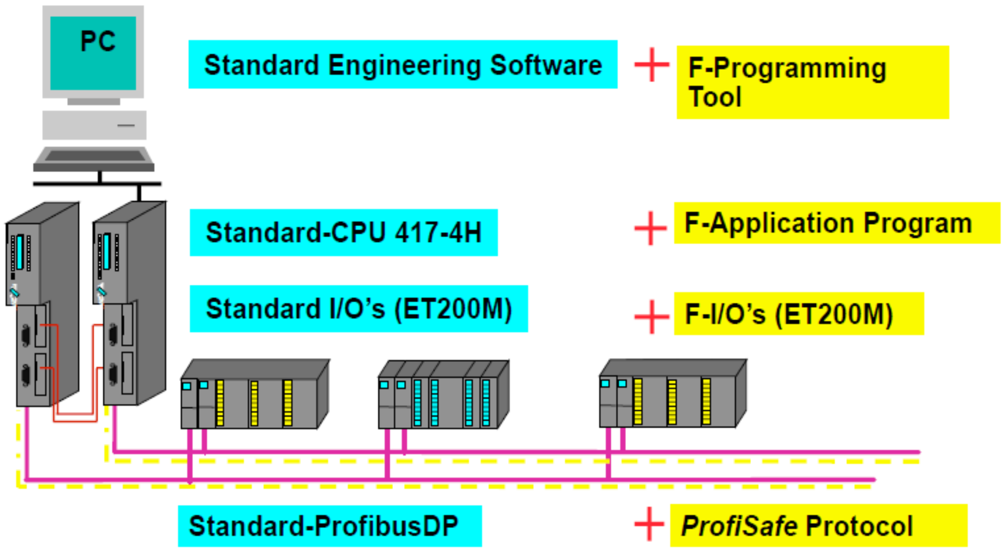


Figure 3-1.Siemens SAS basic configuration (Sveen, 2012).

The basic configuration components:

- Standard CPU: Central Processor CPU 414/417 for the data control.
- Standard I/O & F-I/O: IO Rack ET200 M for the signals from transmitters, thermocouples, etc.
- Standard Profibus & Profisafe protocol: Communications between CPU and IO realised via PROFIBUS communications. For the safety signals is used ProfiSafe communication. Safety system has TÜV verification and built according to IEC61508 standard.
- Standard SW & Programming tool: SIMATIC PCS 7 has common engineering software, operator interface and automation database for the process and safety systems.

The detailed technical data for the SIMATIC PCS 7 is presented in the (table 3-7).

3.3.2 ABB

ABB's latest System is 800xA which was introduced in the end of 2010. System 800xA presents operating environment which allows the incorporation between process and business areas. The 800xA System configuration refers to the (figure 3-2) below.

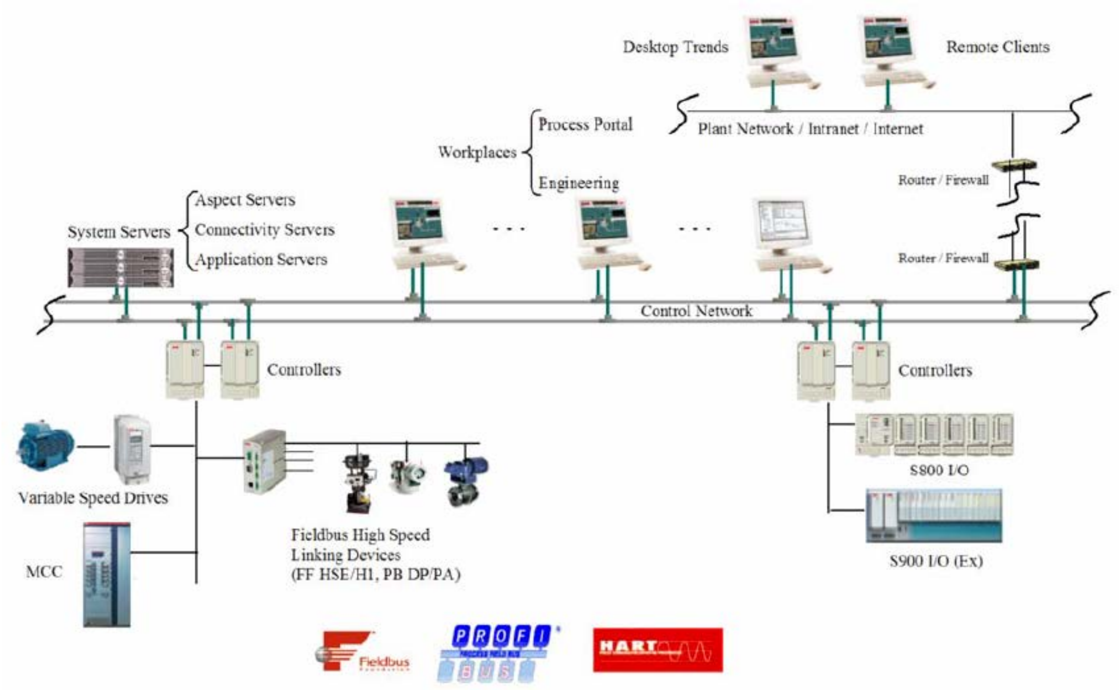


Figure 3-2. The **800xA basic configuration (Industrial 800xA System Architecture, 2003).**

The system 800xA has flexible system configurations and the basic system configuration of the system includes:

- Controllers: CPU AC 800M with available hot standby redundancy for data processing.
- S800I/O & S900 I/O: IO Rack S800 I/O's and S900 Extended I/O's for the signal communication.
- Field High Speed Linked devices: System 800xA has different protocols what significantly simplify the field instrumentation design. Devices are accessed via OPC, Ethernet, Device Net, Modbus TCP, PROFIBUS DP, PROFINET I/O and FOUNDATION Fieldbus.
- System Server: System has server that provides the possibility to configure an operational system.

Safety system has TÜV verification and meets the detailed requirements of the IEC61508 standard. The system has operational interface and automation database for the process and safety systems. The ABB also provides High-Voltage Direct Current Transmission Technologies (HVDC) for the offshore oil field in the NCS. The HVDC method is transportation of current with higher transmission capacity on the longer distances. Current could be transferred with help of underground and subsea cables.

3.3.3 Honeywell

Honeywell has introduced in 2002 their latest system Experion PKS. The Experion architecture combines DCS functionality and a plant-wide infrastructure and suits for both small and large systems. Experion SAS offers DCS capabilities that include Abnormal Situation Management (ASM), Safety Management, and Information Management technologies. The Experion interfaces with FOUNDATION Fieldbus, Profibus, DeviceNet,HART, LON, ControlNet and Interbus. The SAS SafeNet provides the safe communication link between the Safety Manager Controllers on a separate network or by using Fault Tolerant Ethernet (FTE) .The "SafeNet" connection is a SIL 4 certified safety protocol. The ControlNet, Ethernet, or Fault Tolerant Ethernet (FTE) network providing communications link between the C200/C200E and I/O’s .The server can interface to third party controllers such as Allen Bradley PLC5, Modicon, GE Fanuc,Siemens plus many more. The Experion PKS system architecture refers to (figure 3-3) below:

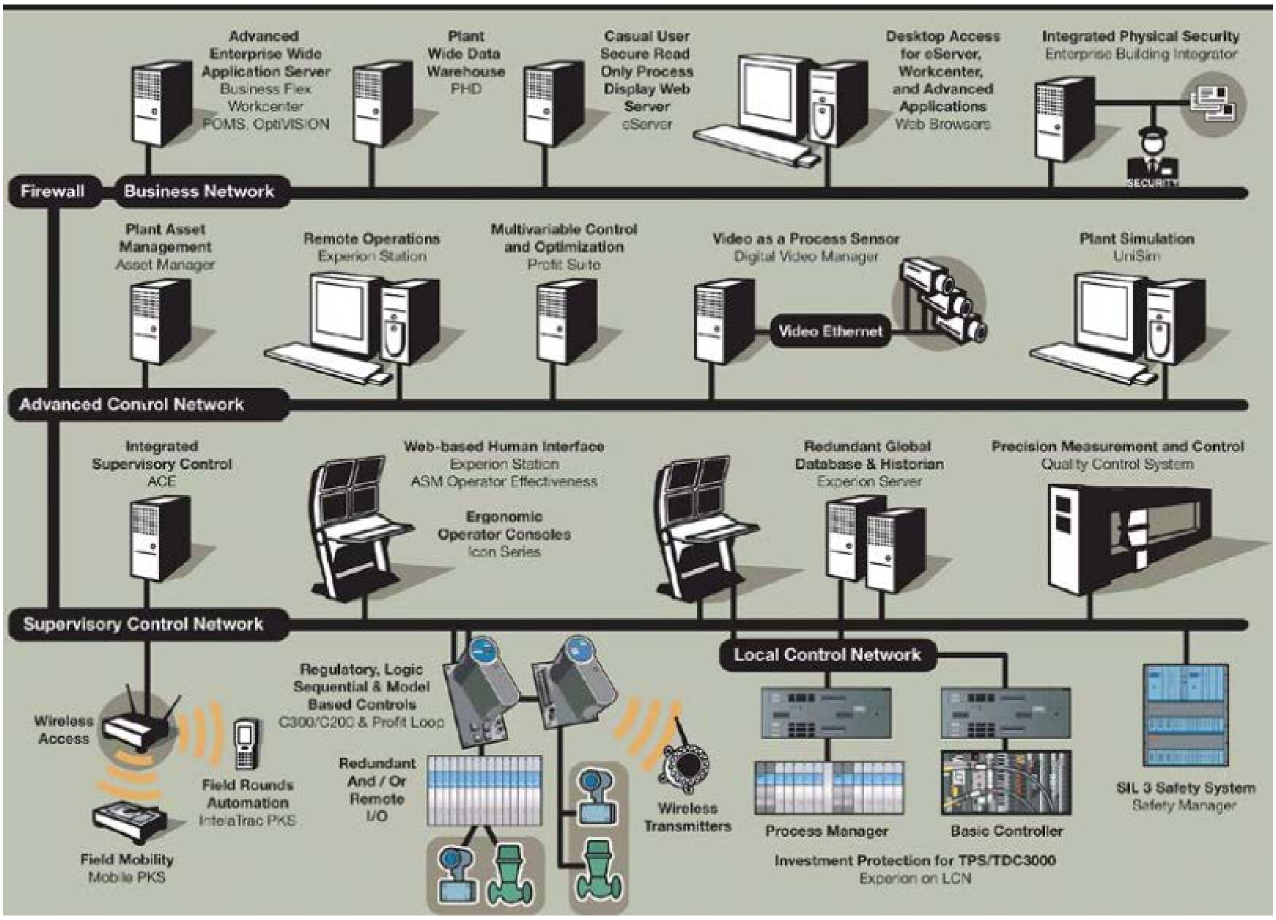


Figure 3-3. Experion Platform Architecture (Experion PKS Overview, 2012).

The basic system configuration includes:

- Regulatory Logic Sequential & Model Based Controls: C200/C200E and/or C300 Process Controllers which supporting hardware components (I/O's) and their placement within the system.
- SIL 3 Safety System: Safety system communicates with dedicated I/O's modules that are directly connected to the Safety Manager controller that integrates in the Experion topology. Safety Manager Controllers can be connected to each other through dedicated network or through the FTE network.
- Process Manager: Process system communicates with dedicated Input/Output (I/O) modules that are directly connected to the Process Manager controller that integrates in the Experion topology.
- Ergonomic Operator Consoles: Stations are Experion's main human interface which uses a series of Web-style displays to present process information in a user-friendly manner.

System could be expanded or upgraded by adding Experion C200/C200E and C300 controllers. These controllers connected through Fault Tolerant Ethernet.
Detailed characteristic of Experion PKS refer to (table 3-7) in the following chapter

3.4 Technical characteristics cross analysis of SAS installations in NCS

This chapter presents technical characteristics cross analysis of the SAS installations in the NCS refer to the (table 3-7). The cross analysis of SAS technical frameworks helps to compare the system's capabilities.

Table 3-7. SAS technical characteristics

Technical characteristics cross analysis for the SAS installations on NCS		
Siemens AS	**ABB**	**Honeywell**
SIMATIC PCS7	**AS 800xA**	**Experion Process Knowledge System (PKS)**
System components :		
SIMATIC PCS 7 could be single or Redundant.	AS800xA could be Single or Redundant	Experion PKS could be Single or Redundancy

CPU's:(AS412-1H/2H)(AS414-1H/2H) (AS417-1H/2H)	CPU's:(PM861A)(PM864A)(PM865)(PM891)	CPU's: (C200)(C200E)(C300)
CPU memory: Max. 2 Gb	**CPU memory:** Max. 4Gb	**CPU memory:** 4 Gb
Programming language: STEP 7 standard: Structured Control Language (SCL) Continuous Function Chart (CFC)	**Programming language:** Structured Text(ST) Instruction List (IL) Function Block Diagram (FBD) Lader Diagram (LD)	**Programming language:** Structured Text(ST) Instruction List (IL) Function Block Diag.(FBD) Lader Diagram (LD)
System architecture refers to Appendix A1-1	**System architecture** refers to Appendix 2-1.	**System architecture** refers to Appendix 4-1.
Operator system:		
Server: Windows Server 2008 or Windows 7 Client: Windows 7 SIMATIC Manager	Server: Windows Server 2008 or Windows 7 Client: Windows 7 VMware vSphere 5.1	Server:Windows7 Client: Windows 7 Engineering tool: Control Building For application is used: "Configuration Studio"
Max. 12 OS servers/pairs of serv. Max. 64 OS areas Max.60000 process tags Max. 4 monitors per OS Max. 150000 configurable messages per server	Max 12 servers (24 if redundant) Max. 80 OS Max. 120 000 process tags Max. 4 monitors per OS Stored OPC message/log 12,000,000	Max. 20 servers+ Max. 5 third party servers Max. 10 OS Max 85000 process tags Max. 4 monitors per OS
Process I/O:		
I/O stations connected via PROFIBUS DP. Distributed I/O system : ET 200M ET 200iSP ET 200S ET 200pro	I/O stations connected via PROFIBUS DP. Distributed I/O system : S100 S200 S900 I/O for hazardous area I/O modules are compliant to severity	Controller communicates with I/O modules chassis via the Integrated Control Protocol (ICP) on backplane and ControlNet Interface Module (CNI).

	level of ISA-S71.04;	
Max. IO modules: Up to 8 modules per each rack. ET 200M(12 per station) ET 200iSP(32 per station) ET 200S(63 per station) ET 200pro(16 per station)	**Max. IO modules:** Max. 128 digital channels can be connected per station. Max. 64 analog channels can be connected per station.	**Max. IO modules:** Max**.** 18 I/O modules per chassi. Max. 64 I/O modules per controller. Max. 24 I/O units per Control Net. Max. 23,808 IO's
Communication protocols: Profibus PA/DP, Profinet, Fieldbus in compliance with IEC 61804-2 Field device message support refer to NAMUR recommendation NE105,107	**Communication protocols:** Foundation Fieldbus, Profibus, Profinet, HART in compliance with IEC 61850	**Communication protocols:** Foundation Fieldbus, Profibus, DeviceNet, HART, LON, ControlNet and Interbus
System Communication		
Industrial Ethernet Communication arranged refers to IEEE 802.3 standard.	**Standard Serial Protocols:** RS232C: MODBUS RTU/TCP, 3964R, Comli **External application communication**: OPC, OLE-DB, ODBC **Network**: Ethernet TCP/IP Redundant	ControlNet for controllers and Fault Tolerant Ethernet (FTE)
Safety system		
SIMATIC PCS 7 using S7-400FH/417FH systems for safety process	AS800xA using AC 800M for safety system. Safety system meets requirements ISO 13849-1.	Honeywell using the same controller. Safety controller work independently from the process control layer.
These F/FH systems collaborate with safety-related F modules of the ET 200 distributed I/O	The practical number of I/Os that can be used in a High Integrity Controller is 500.	Safety Manager Controllers connect through the "SafeNet" with SIL 4

systems or fail-safe transmitters connected directly via the PROFIBUS or PROFINET or PROFIsafe.		certified safety protocol.
The system is TÜV-certified and comply with the safety requirements up to SIL 3 in accordance with IEC 61508	The AC 800M HI controller is certified by the TÜV and complying with the IEC 61508 SIL 1-3 and IEC 61511 standard.	Safety system has comm. module with universal safety interfaces(USI) for exchange information with other equipment

The information used for the cross analysis of technical characteristics refers to: (Siemens publication, 2009) ;(ABB publication, 2013) ;(Honeywell Process Solutions, 2012).

3.5 Functional characteristics of SAS installations: life expectancy, spare availability, maintenance and technical support.

End user companies need information about maintenance performance for planning and controlling the maintenance process. The service offers by SAS vendor manufacturers provides effectiveness and efficiency of the maintenance process, technical support, knowledge and trainings necessary for the process performance, available spare parts, organizational activities, cooperation and coordination with other units of the organization.

This chapter provides cross analysis of services and support which three different SAS vendors companies provide in the NCS.

3.5.1 Siemens

Siemens provides wide spectrum of support for their offshore installations:

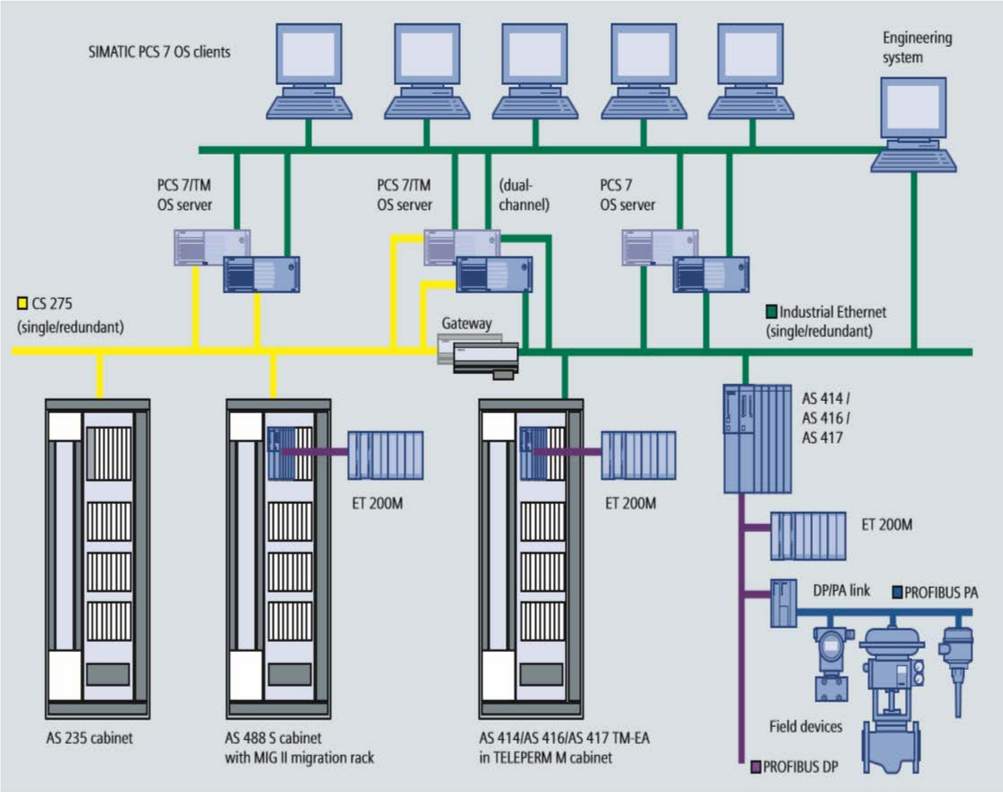
- Technical support: includes on-line support via Internet Webpage, where Siemens has technical documentation, guidelines and manuals. Information regarding Siemens SAS is continuously updating and in addition 24 hours on-line support available.
- Trainings service: Siemens offers training for the customer engineers who operating the plant and machinery.

- Maintenance service and support: Siemens offers maintenance service, installation, commissioning and post commissioning support at site and provide service for preventive maintenance by monitoring through real-time condition analyses.
- Spare part & repair service: Spare part logistic and obsolescence management offers to the end users original spare parts if needed and eliminates the problem of storage space for the user companies.
- Migration & retrofitting: includes hardware and software upgrades Since PC operating systems, control technology and application software cannot be maintained indefinitely on existing hardware, Siemens offering migration service of current system with enhanced futures.(Siemens brochure, 2013)

Siemens has established 10 possible approaches to migration. Ten approaches address each major layer of the control system architecture. These ten layers include:

- HMI Connectivity
- HMI Conversion
- Enhanced Batch Management
- Engineering Library Conversion
- Application Conversion
- Control Network Gateways
- I/O Gateways
- I/O Replacement
- I/O Interfaces
- Field Termination Assemblies (FTA)

These ten layers are grouped into three primary areas of migration that address the three typical areas of a migration project. Siemens migration strategy refers to (figure 3-4).



Fifure 3-4. TELEPERM M process control system Migration to SIMATIC (PCS 7 Brochure, 2008)

Siemens Life cycle strategy as said Ward Beullens, head of System Technology: "*On average, our plants shut down once every five years. We need clearly defined procedures for service processes so that everything runs smoothly when the occasion demands*".

Example of one life cycle time analyse is refer to the (figure 3-5) below:

	Description	Number of order numbers	As a percentage	Number of items
7	Availability horizon > 5 years	33	58,9%	131
6	Availability horizon 2 to 5 years	1	1,8%	4
5	Availability horizon 1 to 2 years	3	5,4%	6
4	Availability horizon < 1 year	0	0,0%	0
3	Item has been totally discontinued, or successor only conditionally compatible	16	28,6%	1.661
2	Item has been discontinued and no successor has been defined; repair or replacement may be possible to a limited extent	2	3,6%	4
1	Unknown order number	1	1,8%	2
	Total	56	100,0%	1.808

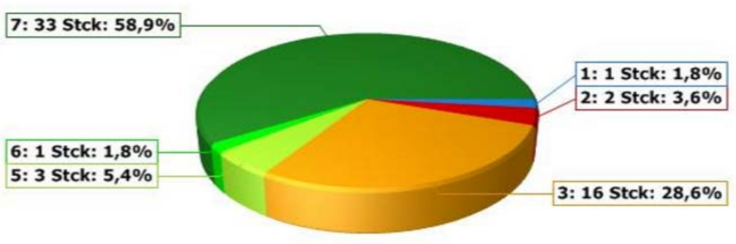


Figure 3-5. Extended analysis report (Answers for Industry, 2013) "*Lifecycle Information Services*")

Analysis of installation has to be carried out for the life time evaluation and next questions need to be responded: What is initial situation and consistency check? What is other product lifecycle? What are the current third party availability / deliverability?

3.5.2 ABB

ABB provides the end user company with the full support of their installations:

- Maintenance and Field service: ABB provides maintenance service during the all life cycle time of their installations.
- Advanced Industry services: ABB offers Real-Time Production Intelligence (RTPI) product for the real time performance indication. The RTPI continuously monitors production processes and records events that can cause production losses or degradation of performance. By storing relevant information as it occurs, RTPI analysis provides users with root causes event that contributes to the process performance.

- Data Acquisition and Reporting (RADAR): ABB offers remote access for power generation processes which provides continuous assessment of the plant condition and transfer of this data to remote support centre. RADAR enables early detection of degradation or faults, which allows remote experts to identify corresponding corrective actions sooner and with lower costs. The same system was applied for the BP Valhall Re-Development Project (VRD).

- Support & Remote services: ABB offers remote monitoring capabilities through the Internet or direct line connections, experts can directly access systems to support corrective and maintenance processes. ABB remote system monitoring services provide data collection, detailed network analysis, system health check, control evaluation and optimization, and web-enabled analysis and troubleshooting. Remote support and diagnostic provides expert help at any time and any location what is significantly reduce any risk of plant or process stoppage.

- Training services: ABB offering classroom training, e-learning, on-site training.

- Consulting services: ABB's provides Automation Technology Consulting service help and support and offers a maintenance outsourcing for all maintenance activities or individually selected asset classes such as motors, drives, analysers, etc.

- Migration & Retrofit services: ABB offering migration solution whenever there is a need to replace a product from ABB or any other manufacturer due to lack of spare parts and limited services. ABB system is designed to be upgradable. This can be a software upgrade on the original hardware, or a complete system upgrade including new hardware, new functions and increasing the performance. The ControlLogix based module that makes the migration and allows the DCS data blocks to be mapped into ControlLogix tags. The ControlLogix controller and the existing system run simultaneously. This allows perform conversion of the DCS in phases as opposed to one big changeover.IO migration requires redundant bus with bus switching modules. But sometimes it is more economical to modernize the old installation by reusing all relevant parts of the original equipment and purchasing new where necessary .In this case ABB has retrofitting service which is normally caring out during planned production shutdown, without causing extra production downtime (ABB technical materials, 2009).

- Spare parts & Repair services: ABB offers exchange units and reconditioned parts, which are more economical alternative. (ABB technical materials, 2009)

For the spare part and life time control ABB has life cycle management program that controls spare parts and availability throughout the life cycle, provides a smooth migration to new technology at obsolete phase of installations. Program helps to analyse if upgrade, retrofit or replacement is required. ABB Life cycle management model refers to (figure 3-6).

Figure 3-6. Product life cycle management model (ABB Life cycle services, 2009)

Each phase has different implications for the end user in terms of services and support.

- In the ‘active’ phase ABB provide warranty, maintenance and support of the system, spare parts and maintenance materials. During this phase end users might realise migration or retrofitting in order to improve performance and extension of the life cycle.
- The ‘classic’ phase starts in the end of production and users are recommended to start planning a transfer to new technology. The spare part services continue as long as components and materials are available.
- The ‘obsolete’ phase comes when it is no longer possible to provide life cycle services within reasonable cost and ABB could no longer support the product technically and old technology is not available (ABB technical materials, 2009).

The average life cycle time for the ABB’s products before it reaches obsolete phase over 10 or 20 years. The life time depends on complexity and functionality of product. More often automation products need upgrade and retrofit rather than full reintegration or demolishing. For example Statoil Hydro control systems upgrade at Gullfaks A, B and C in the North Sea in 2005. In the 1980’s ABB installed the original control systems on this platform and it was no modifications done for 30 years. The main goals for the project modifications are to prepare Gullfaks with the automation technology, topology and competences necessary for Integrated Operations (IO) and to enable tail-end production through to 2030.The main criteria of SAS project implementation is solution shall not limit the implementation of work processes, both offshore and onshore (ABB technical information, 2009).

3.5.3 Honeywell

Honeywell provides technical support for their SAS installations defined below:

- On-site support: This program offers software support, database and site installation, commissioning and service issues support.
- System Optimization program: This program provides condition monitoring and ensures better performance. The System Optimization Program analyses all aspects of a system operation, application SW and database files.
- Software support program: This program updates the end user with the latest Honeywell software and minimizes support costs.
- Recourse and task management service: This service coordinates and manages all third-party interactive tasks and coordinates all tasks between engineers and the end users.
- Remote support service: Enables access over the Internet using any browser, across firewalls and proxies. This program viewing process remotely, diagnoses and performs operations and reduces the cost for the end user company. Communications and support session data is protected against unauthorized disclosure or undetected modification
- Training service: Honeywell’s open access for the end users to their online training program and professionals support can simultaneously train the staff how to perform those steps in the future.
- Migration service: Honeywell provides System migration solution to their system or other third party equipment. Information available from their website (Honeywell, 2014).Honeywell offering:

- Incremental HMI and controller solutions.
- Rip and replace migrating solutions.

To extend the life of current installation or expand capabilities, Honeywell uses their “ControlMatch” engineering tool refer to (figure 3-7) below which allows smooth process migration.

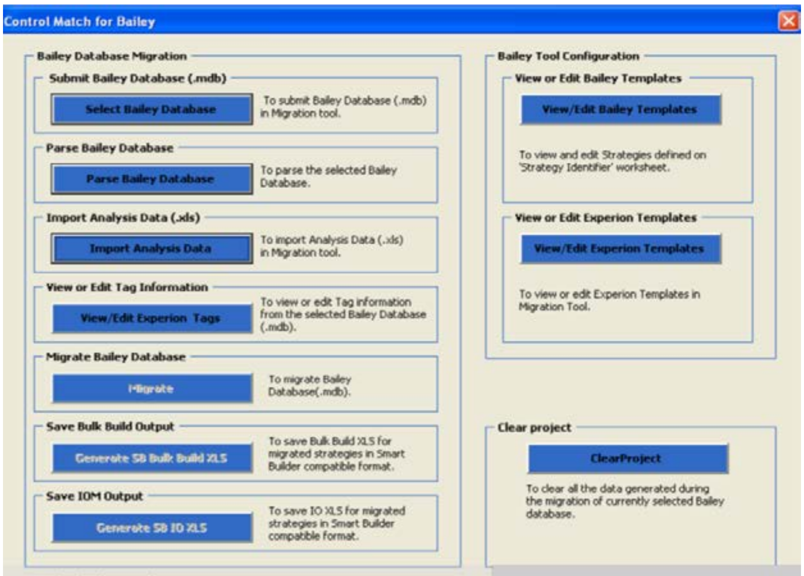


Figure 3-7. Migration Options (Comtois and Ochsner, 2012)

For IO bus migration Honeywell offering solution refer to the (figure 3-8) below

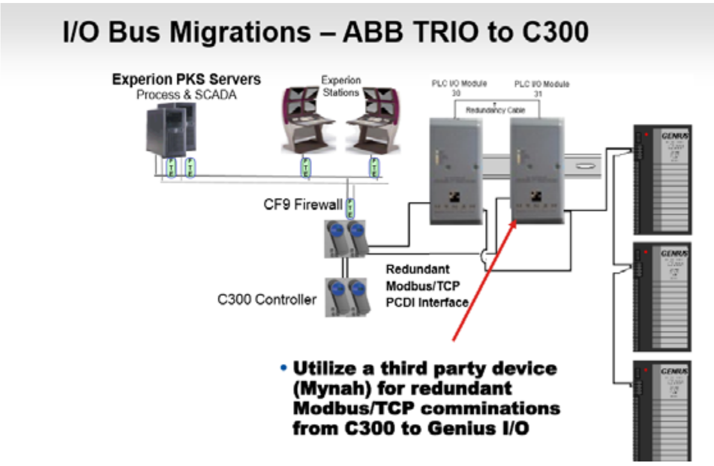


Figure 3-8. Migration Options (Comtois and Ochsner, 2012)

Summary of Honeywell's available services refer to (figure 3-9) below:

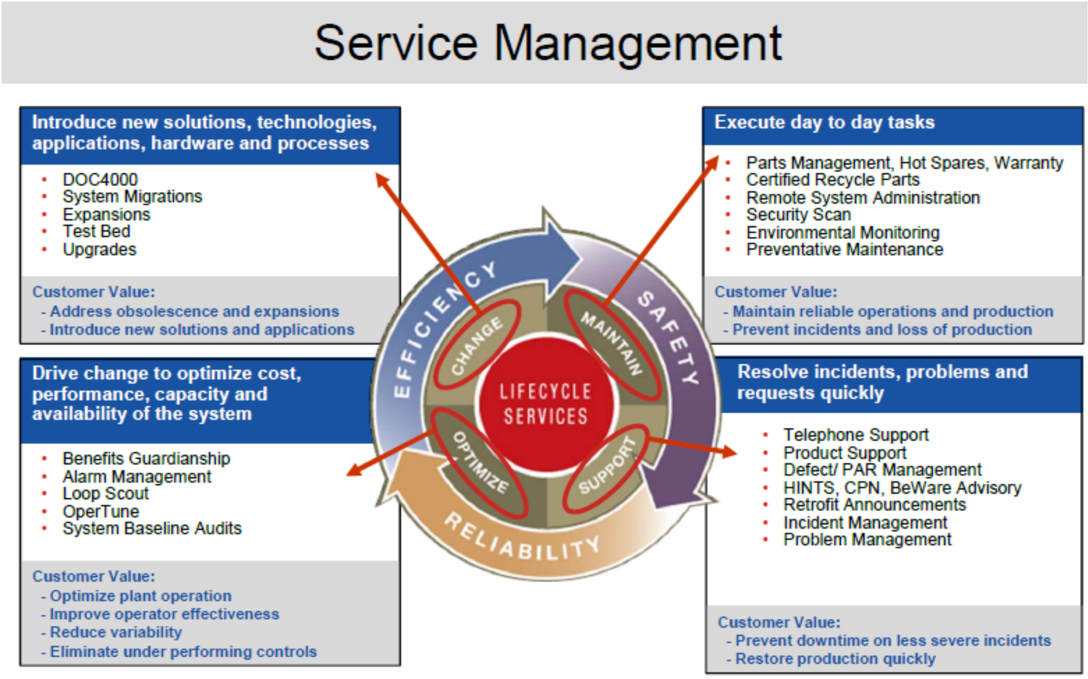


Figure 3-9. Honeywell Service Management (Journal of Petroleum Technology, 2009)

Life expectancy and spare part availability of Honeywell distributed system has more than 30 years. For example Honeywell still support Legacy system, which has been installed in the 70's. Honeywell offers the Life Cycle Management program (LCM) that offers flexibility in the managing of plant assets and flexibility in modernization of system components. LCM provides customers with a cost-effective path forward to the latest technology and functionality.

"*Our agreement guarantees them protection from obsolescence, a consistent and cost-effective migration path, and access to parts and technical support - all locked in at today's pricing for up to the next ten years*," said Steve Boyazis, Honeywell ACS Service's director .

3.6 Operational features of SAS installations in NCS

In the chapter above were identified functional, operational and technical characteristics of the SAS systems. This chapter shortly provides operational features of each system.

3.6.1 Siemens

The Siemens SAS has quick response to the market changes in a way that creates sustainable competitive products. The strength of the automation system from Siemens is continuous modification and development of their products. The company also provides continuous support and maintenance of their installations and spare parts. Company provides 24 hours hotline support, trainings and on-line update of the system.

3.6.2 ABB

In April 2014 ABB announced that they present the latest 800xA version 6.0 which represents the temporary peak of development automation system in conjunction with IT technology and will cover all possible gaps in the condition monitoring and diagnostic ,maintenance ,system support and managements control. The ABB strengths is wide spectre of products that makes end user customers more interested in the system since integration of SAS components is much easier if they have the same manufacturer, the same time ABB automation system is tightly integrated with the third party. Other strength of ABB SAS is capabilities to combine permanent products development with services and solutions.

3.6.3 Honeywell

Honeywell provides DCS and SCADA solutions. The SCADA due to mobility of the system prevents the SAS from obsolete phase and it is very economical design for shifting from one generation to another without high cost with high efficiency. Honeywell focus on innovation modernisation and optimisation of automation system solutions. Another positive feature of automation system is long time support. Honeywell still support their first TDC 2000.The Experion PKS has remote support of the system and remote access to the process and control what is quite simplify the system support.

3.7 Current clients of SAS installations in NCS

This chapter provides the projects in the NCS which uses SAS described in the chapters earlier and demonstrates the right choice of the systems. The list of the projects shows that SAS market in Norway mostly shares between three chosen SAS vendor companies.

3.7.1 Siemens

In 1985 Siemens SAS had their first large SAS installation for offshore Oseberg (15 000 safety I/O). Currently Siemens SAS well known and widely used in the NCS. Siemens has about 30% of

SAS installations in the NCS. The oil fields where Siemens SAS used for the long time are listed in the (table 3-8) below.

Table 3-8. Siemens SAS installations in NCS (Sveen, 2012).

Brage (Wintershall Norge)	Since 1992
Eldfisk (Conoco Phillips)	Since 1991
Ekofisk (Conocophillips)	Since 1995
Njord A &B(Statoil)	Since 1995
Huldra (Statoil)	Since 2000
Petrojarl Foinhaven	Since 1996
Oseberg (Statoil)	Since 19985
Snore A&B&TLP (Statoil)	Since 1990
Stena don (Statoil)	Since 2000
Statfjord (Statoil)	Since 2000
Troll C (Statoil)	Since 1999
Visund	Since 1998

3.7.2 ABB

ABB provides with well-known SAS in the NCS and has their installations all over the NCS. Apart from automation system ABB is offering HVDC service worldwide refer to (figure 3-10) below, and still has some space for developments and innovations in this area.

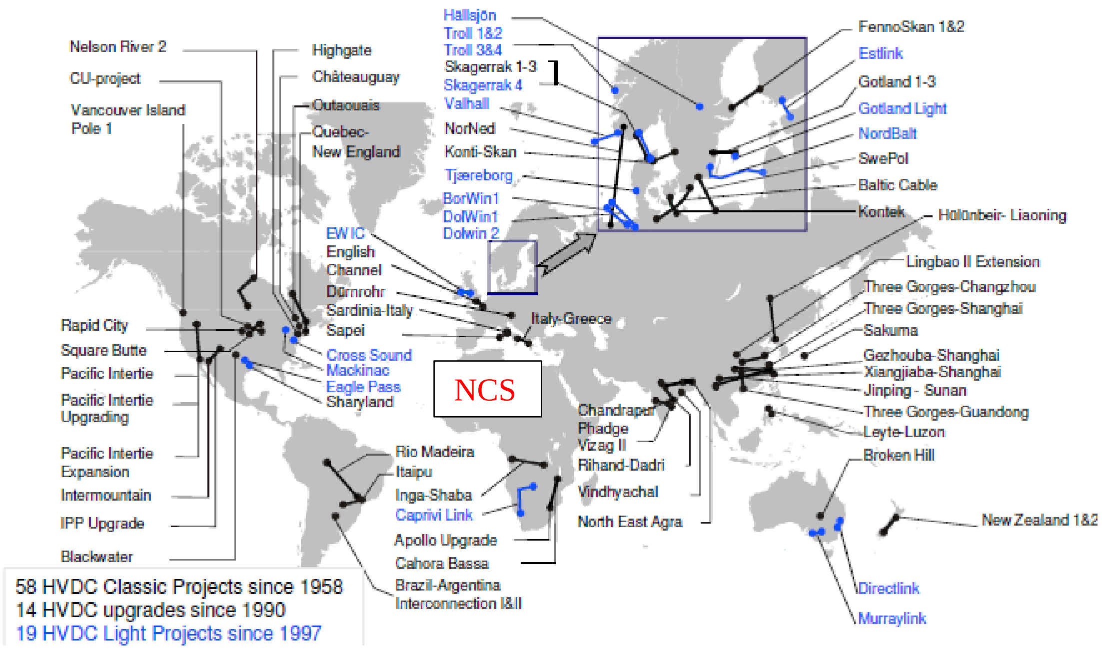


Figure 3-10.ABB HVDC installations

The latest SAS projects modifications with ABB in the NCS are listed below in the table.

Table 3-9. Latest ABB SAS implementation projects

Heimdal (Statoil)	Signed in 2013
Gullfaks A (Semco)	Since 1986
Aasta Hansteen	Future delivery by 2015
Gina Krog	Future delivery by 2015
Asgard (Statoil;Petoro ; Eni Norge;Total and ExxonMobil)	Signed in 2011
Goliat(Eni &Statoil)	Future instalations

3.7.3 Honeywell

In 2012 Honeywell's SAS has been selected by Statoil for Valemon platform in the North Sea, one of Statoil's largest development projects. Honeywell's SAS can provide remote operation of the process. The entire operation can be operated remotely from the existing Kvitebjørn platform.

Currently Honeywell SAS is new in NCS but this system has all characteristics and prerequisites to become a well-known and demanding SAS in the NCS.

3.8 Main focuses for SAS determination

Each system has its strengths and challenges. In order to determine the automation system during design phase several aspects of the system has to be compared:

- Technical characteristic of industrial processes.
- What are the costs of SAS in comparison with functionality and abilities of the system?
- Which standards were followed by manufacturer for system configuration?
- How much support is in the area for the SAS system?
- How old is the system (how close is it to becoming obsolete)

Chapter 4

4. Challenges related to SAS project implementation, products and services provided by SAS manufacturers

This chapter identifies the challenges and gives ideas which have to be considered during SAS project implementation. The challenges of SAS project implementation appear due to complexity of the oil and gas process which involves expensive and critical technology. The introduction of new information and communication technology changes the work processes and ways of doing oil and gas exploration and production. Integrated Operations introduce new ways of working. “Integrated operation means changes to organization, staffing, management systems and technology and not least to the interaction between them” (PSA, 2009).

4.1 Integrated Operations

Integrated Operations were first introduced in 2003. The new development scenario in O&G industry in NCS becomes a program with national interests and was accepted by major part of the industry.

Today this scenario is gradually growing in day-to-day practices (Liyanage and Bjerkebæk,n.d.). Integrated Operations or e-Operations are new forms of operation based on real-time data to integrate work processes between disciplines, offshore, land and different organizations. The purpose of this is to achieve process faster, and possibility to make a better decision. E-Operations are innovations in the oil and gas industry that becoming quite challenging during the SAS project implementation. Integrated operations involve the use of advanced monitoring tools and technologies, remote operations, remote performance measurement, remote field optimization to increase competent intelligent automation, use innovative ICT technology etc. Implementation of IO in the oil and gas process demands changes in the SAS functionality and demands that system must be architected to interoperate across assets, operations centres and corporate boundaries in a timely and secure manner. With the development of automation and instrumentation technology gives the access to process data and with more data available users are able to make better decisions and reduce the operational cost.

In the Norwegian oil and gas industry, the objectives of establishing integrated operation and maintenance plan was based on challenges and opportunities to improve the oil and gas industry in terms of efficiency, productivity, safety and security (Liyanage ,2008).The Norwegian Oil Industry

Association (OLF) has defined the term Integrated Operations (IO) as “real time data onshore from offshore fields and new integrated work processes”. OLF developed IO strategy which requires data sharing in real time among the stakeholders. The strategy was developed based on ISO 15926 standard. The (figure 4-1) illustrates adoption of IO operation by OLF guideline on the NCS.

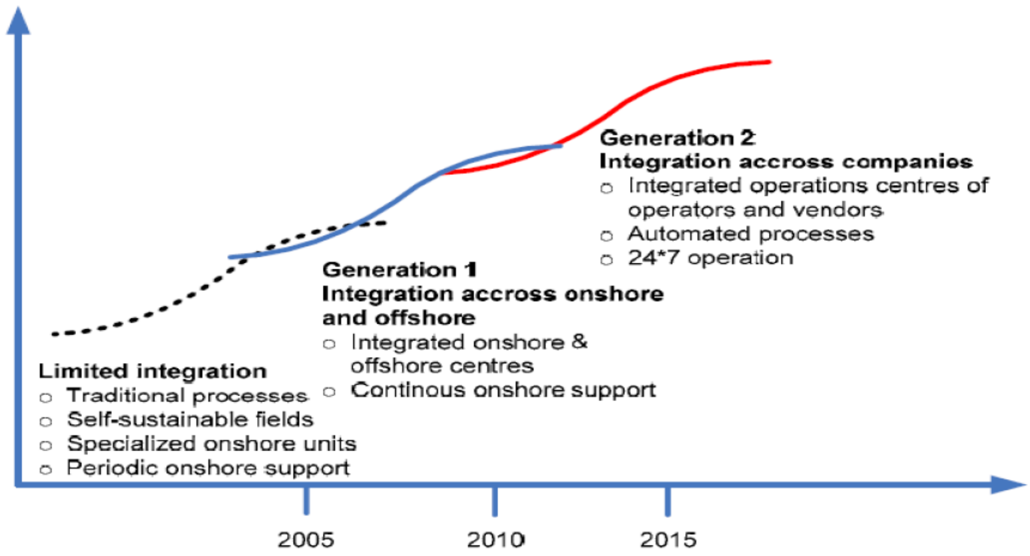


Figure 4-1.OLF strategy of implementation IO (OLF, 2005).

- Generation 1 activities include integrated onshore and offshore centres which optimize of work-processes by fast access to the process and easy communication between onshore and offshore.
- Generation 2 activities include development of new generation IT technology designed to transform huge amount of data into decisions and advice from professionals onshore.

Today’s companies more focusing on the implementation of generation 1 solution. And challenge which companies faces is that IT solution does not support the new concepts of operation architecture. In the NCS there are not so many projects that widely apply IO because development and implementation of IO requires development of technological solutions in wireless communication and sensor technology, robotic technology etc. Oil field with an integrated condition monitoring and integrated control is still a future development in the Oil&Gas industry on NCS which is rapidly developing and embedding. (Bindingsbø and Vatland, 2008).

“Implementation of these practices will lead to relatively simple but profound changes to the traditional work processes” (OLF, 2005)

4.2 Technological changes

The changes in technology has significant impact on the SAS solutions available in NCS and keep it in the continuous modifications in order to provide qualities, scalability, openness to third-party systems and capability of integration with other solutions. The technological changes lead the changes in the other areas such as IT technology, communications technology, sensors and instrumentation, process data condition and monitoring etc.

4.2.1 Changes in communication technology

The rapid developments within data acquisition and offshore-onshore communication technologies lead to the changes in operational practice. Development of new technology demands the new way of people and data communications. The work process between land and sea demands new performance approach and tools like 3D-visualization videoconference rooms between offshore platforms and land-based offices, broadband connections for sharing of data and video-surveillance of the platform (Johnson, 2009).The active usage of IT technology can bridge data between the different locations, use online and offline sources to provide recommendations and real-time targeted offers based on real-time analysis of process behaviour. The real-time measurements of the process data demands improvements in the measurement devices, better aggregation and visualization of information. Improvements in the automations and instrumentations give real-time production optimization through IO.

4.2.2 Condition monitoring changes

The maintenance and role of maintenance in the petroleum industry had major changes from generation to generation. John Moubray presents the evolution of maintenance expectation and maintenance approach for different generations with explosive growth in the new maintenance concept and technics:

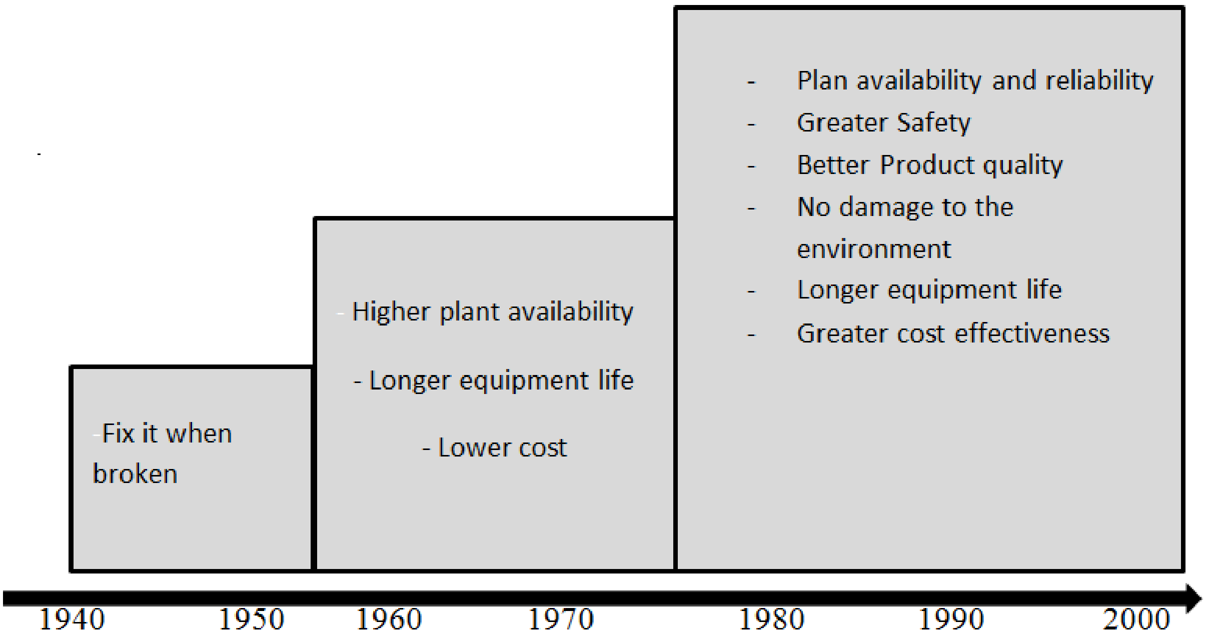


Figure 4-2. Growing expectation of maintenance (J. Moubray, 2007) "*Reliability-centred Maintenance*")

For the last ten years it has been changed even more due to the huge increases of oil field exploration, complex design, changes in the techniques, changes in the roles and responsibilities. The main maintenance tool which is widely used in the different industry is condition monitoring. Condition monitoring becomes a powerful management tool for environment control, maintenance planning, on-line process data monitoring, quality and maintenance cost improvements. Automation systems are used for the condition monitoring processes. Condition monitoring techniques provided by SAS vendor companies includes:

- Maintenance costs reduction.

Condition monitoring tool provided by SAS vendors companies gathers information for the diagnosis of eventual faults on equipment. This helps to detects faulty condition at their earliest possible stages and predict "correct" maintenance based on actual condition. Earlier problem identification is much cheaper .Failure of equipment also could have a domino effect on other parts of the process and might lead to long time downtime or secondary damage.

- Equipment lifecycle increase.

Earlier failure detection and just-in-time corrective action increase the life of equipment and its utilization. By increasing lifecycle of equipment users also decrease numbers of spare parts and as a sequence solve the problem with storage place for the spare parts. Less number of spare parts significantly reduces initial cost.

- Risk reduction and safety improvement.

Early detection and fault elimination, increase environment safety and safety of personnel. Failure of one minor component could have critical effect on whole system and as earlier detection is eliminated as less risk. Safety systems are used for detection and elimination of all possible danger situations.

- Maintenance planning.

Condition monitoring analysis displays maintenance relevant data and evaluates system plant conditions what is significantly minimizes production downtime and helps to schedule downtime periods.

- Remote access

Condition monitoring SW tools provides remote access to the process parameters and monitoring independently of process location. SAS vendor companies offer variety of engineering tools and technology for the process condition monitoring. For example IMS applications, smart instrumentation diagnostics information such as Partial stroke for safety valves. Safety critical equipment can be monitored and integrity information made available. Process data, active work orders and work permits can be visualized in the interactive information displays. Condition monitoring market has a potential for future development because end-users are constantly adopting different condition monitoring programs for its needs. The SAS vendor companies also undergoing intensive research and innovate their products and monitoring technologies capabilities in order to response demands and business needs of their clients. Some of the condition monitoring techniques become functional requirements for the SAS implementation: "*The Information Management System (IMS) shall be connected to the SAS units in such a way that all data in the SAS units can be selected, processed and presented on IMS terminal and in reporting form. The IMS shall be configured with hardware and software for connection to the installation office data network. The IMS shall have programming tools that make it easy to create historical reports for blockings, production data, operational logging, maintenance data, alarm system with searching and sorting facilities etc.*" (NORSOK I-002, 2001) .Companies products also depends on the standards requirements and as soon as IMS system is one of the requirements of the NORSOK standard then manufacturers have to provide and support of this solution for the SAS .

4.2.3 Intelligent automation changes and development

Intelligent Automation is automation with high availability, easy reconfiguration, flexibility and other innovative developments. Automation systems todays have intelligent power distribution networks, wide range of embedded network innovations, wireless sensors for having an online continuous real-time measure, on-line process monitoring and diagnostic. Smart sensors and instrumentations allow performing self-diagnostics and monitoring functionality, interfacing to transfer values to the above mentioned data collection for performance of condition monitoring.
The new developments in the intelligent system affect the SAS control and more often demand SAS intelligence solutions during the process. SAS Intelligence solutions are a suite of automation tools that enable organizations to transform data on long distance and makes high-performance process that is a highly available and scalable. Example of use intelligent automation in the NCS is BP Valhall Re-Development Project (VRD).The equipment on the Valhall field will be supplied with electric power from shore, through a HVDC Light transmission by ABB. This is the first time HVDC is used to supply an entire offshore system. This involves less maintenance, longer lifetime and higher availability. The Valhall project is planned to implement Integrated Operations solutions and integrate new platform into existing Brownfield facilities with control provided from the BP's onshore offices. It gives possibility to move some personnel onshore and instead of keeping specialist on every platform, expert could be located onshore and be available for consultation for several offshore platforms. This integration across organization will certainly involve reorganization and restructuration.

4.3 Operational and Organizational changes

Significant changes and modifications happened in organizational processes and customer-client relationship from adversarial and profitable oriented to open-door relation with priorities such as reliability, consistency, quality, just in time delivery. (Maskell, 1991).
Organizational changes have been implemented step-by-step. In different decades organizations had different performance driver priorities and focuses. Now days customer do not buy goods or services, they buy benefits provided them with: consistency, reliability and 24 hours service, information, personal attention and other components.
Business goals have changed towards using a scalable controller platform possessing multi-functional capabilities with fastest requirements changes adaptability, maximum availability and

transparency. The driving forces behind SAS selection are continuous productivity, improvements and increased profitability. Due to changes in the organizational process demands SAS manufacturers had to change they business management strategy and operational approaches towards improving their product services, maintenance and support. The SAS vendors companies today have wide spectre of services and 24 hours support of the system all the way till the system obsolete phase .SAS manufacturers offering different solutions for system condition control and maintenance.

Other significant changes happened in customer-client relationship and management. Many companies change their management strategy to a customer-focused relationship and raised it as a potentially important factor. Traditional manufacturer mostly had adversarial relationship with customer, and procurement personal was rewarded for getting lowest price. Now days there are variety of approaches to client relationships, but it is always open-door policy with priorities such as reliability, consistency, quality, just in-time delivery (Maskell, 1991).The relationship boundary elimination happened not only towards the client, but also internally in the company between management and personal. The new strategy of management performance more focused on the result and best way to achieve desirable result, and not focused on subordination and responsibility. The main features of boundary-less organization it is flexibility of employees in their job, where everyone could be decision maker and take initiative in the performance of the job, without any criticism to the creativity and initiative. This way of performance management is more progressive and productive (Frankel, 2008). These organizational changes have effect on the SAS project implementation process decision and design phase. Users companies are work in close relations with the SAS vendor companies and they take decision in collaboration.

Another organizational change is outsourcing acceleration. The progress in telecommunications and computerisation opened possibilities for global outsourcing of various business activities from different places where the labour supply is both cheap and plentiful. Outsourcing significantly reduces of in-house skills and increases contractor's service. This way client companies prefer outsourcing instead of spending time and finance for the personnel development. The outsource service started from food and cleaning service, but today maintenance is one of the most commonly outsource services (Nicholson, 2008).Current days SAS vendor companies using outsource service for HMI design or software production or other jobs . Applying outsource service reduces the capital cost and accelerates the process of SAS development and implementation. The outsource service could initiates the human factor challenges. Human factor is another important challenge which has to be considered during SAS project implementation. Human factor effect during design and implementation phase is discussed in the following subchapter.

4.3.1 Human factor

Technology is developing very fast and gives great benefits for human being, but also has great potential of hazard, because it is becoming more complex. And can be also result in deaths and misfortune, but even if error has happened, the case should be carefully investigated, and lesson learned.

The humans have the major roles in the exploitation of SAS. The many rules; standards and regulation was developed and modified in order to make system exploitation less complicated for the people. Refer to ISA S5.5 “Graphic Symbols for Process Displays”. The standard regulates graphical symbols and process displays and establishes uniformity of process visualisation through the industry.

The other SAS parameter that has been modified is Alarm management system, since interpretation and clear understanding of alarms is important process control knowledge. Alarm management has become a highly important topic, and the subject of articles, technical symposia, and books. That was the prerequisite for issuing ISA 18.2 Alarm Management Standard in 2009.This standard about the work processes of people. The standard indicates a collection of activities that may be done as mandatory or recommended. For example: ensure alarms meet the criteria set, forward in the alarm philosophy, justify the need for the alarm, determine the proper priority, document relevant information etc.

New technologies, new ergonomic standards, and increased public awareness of workplace health issues have combined to inspire shift in console design. Today’s design of technology demand smaller size with more functionality and ensuring existence that every aspect of Interaction between human, machine and the environment is taken into account. The international standard ISO 11064 require certain standards of control room ergonomic user-centred design. During operation of complex system it is impossible fully predict their behaviour and impact on such systems. Safety standards should be an aid to handle it in a safe, efficient and effective manner. Standards adapt several strategies related to humans as parts of safety-critical and safety-related systems refer to ISO 11064 standards is used for design of control system with regards to human errors. Human factor have to be taken into account during design of equipment because people going to use and maintain it. System design has to be compatible with human needs and capabilities, they have to know about system and how the system developed. After construction people normally have to be trained to operate the system.

Another challenge that people are varying in their education and physique, and since plant and machines have to be operated and maintained by humans, then all personal factors have to be taken into consideration during design phase. Sometimes we can notice tendency, that for young generation with a good amount of technical knowledge is easy to adapt to the hectically changes in technology , but for older generation it could be frustrating and intimidating to go through the learning curve to get the device to help them do the desire task. Manufacturer companies have to evaluate human respond in the available time since human being has emotions that could affect the way of they behave and respond to the work. (Redmill and Rajan, 1997). They have to analyse who is the user and what knowledge and skills and abilities they have and how quick user can use the new software without any questions, if it is enough to provide job aids or training have to be arranged. (Bailey, 1996). SAS performance parameters standards and regulations have to be kept in order to unify performance of control process and reduce human factor error.

4.4 Standards and regulation changes effect on the SAS modification

New requirements in the petroleum process sometimes demand the changes in the SAS and functional specifications. The standards development is collaborative process between standard bodies and operating companies, decision-making process based on the industrial needs and experience. The open standards approaches applied in the oil and gas industries give the benefits to the operators and reduce the fear of losing the system data. The frequent changes in standardization that relates to SAS implementation is happening in the (ICT) industry. The ICT industry continuously changing compatibility in network externalities and enabling communication infrastructure and communication protocols for system interface capacity. Any changes in the standards related to the SAS that require modifications need to be taken into account during system life cycle time.

4.5 Changes in Safety Systems control

SAS had significant changes towards protecting environment and humans from injury or death since during the everyday work there are different challenges in keeping of safe industrial culture. The employees work under demanding safety conditions, the company use a lot of people with different languages and from different national cultures, the employees have to work with different customers and they have to learn new disciplines when it's needed. The work has a strong focus on safety and people coordination in order to ensure that they have right competence as well as the right attitudes towards safety.

Changes made for the safety system based on the operating process experience and aimed to increase the productivity or to reduce the risk level. The safety automation systems are complex and demands deep analysis before any modifications. Only dedicated specialists allowed doing modifications in the safety systems since changes may have a significant impact on the system and the working personnel. Modifications in the safety systems often have cascade-effect. Due to one modification, other functions may be affected.

The most used standard in the NCS for the safety systems implementation are: IEC 61508/61511 international standards, OLF-070 guideline, NORSOK I-002, S-001. These standards define performance and acceptance requirements with respect to the technical, operational and organizational elements.

For example acceptance criteria for safety barriers used in the NORSOK S-001 states : "*fire water system shall be designed and calibrated such that the deluge nozzles will receive water at design pressure not later than 30 seconds after a confirmed fire signal has been given*"

Based on stated regulation in the NORSOK S-001, operating companies have to fulfil requirement and made the full analysis of installed deluge process; implement the new requirement and retest the system.

Although some reports show that technical barriers is one of the most difficult problems faced by operators, because it's often broken. To reduce the risk of major accident ConocoPhillips has developed barrier panel concept. The barrier panel display a performance measurement system for monitoring preventive maintenance activities and the barrier systems.

The openness of standards development eliminate vendors monopoly since the specifications, interfaces, guidelines or rules are open and known, every company could implement the same solution by following the standards. This gives a free choice for operating companies.

4.6 Industrial demand for SAS process modifications

Continuous modernization and development, replacement or migration of SAS become necessary due to technological advancement, changing markets, operational requirements or more stringent safety and environmental regulations.

The power force of these changes is computer technologies changes, telecommunication technologies and media or other words Information Communication Technologies (ICT). (Hendrick,H.W. and Kleiner,B., 2002).

Changes in the ICT world, affects all other spheres of industry especially automation and instrumentations fields. These changes and modifications which were ruled by external world changes in ICT sphere in the management sphere or safety regulations and automation policy was reflected in the SAS technology today.

SAS systems often need modifications and upgrades from an older version of SAS or moving to a new platform or moving to the newer Operational System platform. It is very important to acquire a global view of the system and identify the system architecture and each individual component. One of the challenges is the SAS connection to other equipment databases and analysis tools. SAS migrating to a new version is challenging due to the many dependent components related to hardware, software and humans.

SAS suppliers have significantly expanded their migration offering. The SAS migration strategy focuses on the system transition or modernization in several steps if possible without a plant shutdown or with minimum production downtimes. Each supplier has its own solution refer to the (chapter 3).

Chapter 5

5. Conclusions and Recommendations to possible future demands for SAS implementation

5.1 Possible SAS future demands for the next 10 years

What do we expect from the manufacturing industry of automation system in the future? How far the process of innovations and advance technology will rises up? What do we expect within the foreseeable 10 years future?

The process industry of the future will involve a lot of intelligent automation and will operate faster and more efficient compared to now days since continuously developing of technology and internet functionality drives to increase of customer expectations. If we compare the 30 years ago, the concept of Computer Integrated Manufacturing (CIM) was establishing integral digitally networked and supported production processes. And today there is enormous business potential in the area of automation, networking, environment, business process and security.

Industrial processes went through fundamental changes and continuing its development. Automation systems take over management control, planning, maintenance control etc.The growth of information and communication technologies (ICT) driven by microelectronics, computer hardware and software systems have influenced all organizational process. The Internet has shown impact on automation system development strategy.

Accessing systems resources from anywhere anytime has helped manufacturer to innovate the system performance with supply chain management, customer relationship management, lifecycle management program, advanced planning and scheduling and all other services continue its developing and improving for the next 10 years.

Based on the analysis of the SAS modifications under the changes of standards and regulations it could be proposed that new modifications in the nearest 10 years will not be revolutionary steps in the process development, rather focusing on the safety improvement, improving usage of intelligent automation, involving more robotics control which improve remote control offshore installation from the land and process integration from the different manufacturer into one system. In the following chapters identified proposition for the next 10 years for the SAS development.

5.1.1 Proposition 1: Unification of engineering tools for the condition monitoring techniques

Different engineering tools and applications for the maintenance and condition monitoring purpose will be unify into "single engineering tool" which handle communication , logic associated to the distributed functions, the graphical data shared between devices (alarms, trends etc.).It will make system less complex for all actors in future and eliminate human factor failure. To have unifying engineering tools helps to avoid adaptation period for the users and eliminate the training cost. This proposition is unprofitable for the SAS vendor manufacturer, since all of them have their own developed engineering tools, which are includes in the SAS package. But it is a good intention towards safety and reliability.

5.1.2 Proposition 2: Unification of HMI

The SAS installed in Norway compliance with IEC 61850 what gives possibility to mix the products from different suppliers in the one process area and use one standard business management software instead of using varies from one supplier to another. The standardised software significantly reduces human errors, training cost and makes migration process from one system to another more flexible. Currently this proposition seems unreal because every SAS manufacturers have their own HMI and continuously working on its developments. But in future unification of SAS might be not the only dream proposal.

5.1.3 Proposition 3: Wireless sensor Networks development

The Wireless Sensor Networks (WSN) has become interesting areas of research. The WSN is gradually adopted in the SAS industry in order to reduce cable cost and design flexibility. For example Siemens and ABB offering Wireless HART automation products including smart wireless adapters that can upgrade existing HART instruments. The WSN has a high potential for development due to the high interest to remote operation, cost reduction and safety improvement and it is still has area for improvement of safety aspects such as sensitivity to interferences.

5.1.4 Proposition 4: Power system development

The power system technology that could provide power transmits from widely distributed solar panels, wind turbines, and other sources of renewable energy. In Europe, there's been talk for years of a super grid that would provide power from hydroelectric. The intention is to have more environment friendly power industry.   Siemens and ABB working on power grid solution and next 10 years development might reach the peak of progress.

5.2 Recommended solutions to resolve any gaps in SAS projects implementation

This project demonstrates the main stages for the SAS project implementation and cross check analysis of current SAS installations in the Norwegian Continental Shelf. It is also compare the company's development history and different approach to the service and support of their products. The (table.3-7) provides the technical characteristics of the SAS and could be a helpful for the companies during the design phase of the project.

This chapter will not present any scientific results, but will inquire experience and general analysis and recommendations for the SAS manufacturer in the NCS. The companies must be aware of their challenges, but they seem to believe that these do not pose huge difficulties as long as their treat them correctly.

The general recommendations for the SAS vendor manufacturers are focus on the development of communication technology, integrated operations and smart operations. Development in information and communication technologies has been very catalytic to the progress in technology applications such as diagnostic technologies, remote access communication, wireless sensors, data management solutions etc. This progress indicates great potential for development different technological setting and an operating mode. The focus on development of integrated operations, smart operations,3-D technologies, intelligent and virtual tools are not just new technology and innovations in the oil and gas industry but the way of making operation and maintenance process effective and efficient with help of new technical tools and methods. And since O&G is substantial part of incomes in the country the IO were accepted by oil and gas industry as new organizational activities and gradually becomes a program with national interests and might become one of the requirements for SAS project implementation.

In the sub-chapters below there are individual recommendations for the SAS vendor manufacturer, which were discussed in this project.

5.2.1 Siemens

Siemens has policy to introduce a major new release of SIMATIC PCS 7 approximately every 18 months. The company has progressive policy of product development and less focus on the innovations of the automation system. Undoubtedly the wide specter of the product is big advantage since automation product could be optimally adapted to any process, but Siemens has the gaps in the system innovations development, there is no any development in the robotic systems and integration operations. The company just started to build its presence in production management and has gaps in relationships with third party solutions in comparison with their competitors. The recommendation for the Siemens Automation is to focus on development of smart operation services, remote control development and increase the flexibility level towards integration of third party equipment.

5.2.2 ABB

ABB has different approach to the development of system's component. Continuous development, maintenance and improvement of the systems provides many advantages, but it also requires systematic approach in design planning, extensive development, support of more complex maintenance processes and sometimes unpredictable extra costs. Then higher degree of system functionality then lower capability range for end users to integrate system in the process since it's requires training, and applications knowledge. ABB needs to have more focus on realization of their innovations on the end user side. ABB still has the gaps in IT communication solution for Integrated Operations, but has possibility to develop this area in the NCS.

5.2.3 Honeywell

Honeywell Process Solutions is using universal channel technology to completely liberate safety and process input and output (I/O). The Honeywell's SAS has fully remote control of the process, and has good potential to become widely usable in the Norse Sea, because there are many small platforms with limited access and number of employee due to climate condition. But the big gap of system solution is lack of instrumentations and sensors. Honeywell focuses on the system developments, new solutions for the system execution and innovations and disregards development of instrumentation products. The field level technology development area is recommended to be improved in order to be competitive on the Norwegian market.
The survey revealed that SAS suppliers have some challenges with their current production but their continuously developing their products and services to respond industrial demands and competitiveness on the market.

Chapter 6

6.1 Discussion and analysis

This section evaluates the results which were achieved and possible source of errors in these results. The purpose of this master thesis has been to identify the challenges of SAS project implementation in the NCS. There are several reasons why SAS has continuous modifications in the petroleum industry. However, one of the major purposes considered in most of the organizations is to increase the safety, production performance and business profits. Very often, cost is the most significant concern in business perspectives. One part of this thesis evaluates three SAS vendor companies their technical, operational and functional characteristics .After comparing these characteristics on various criteria such as maximum number of process objects, maximum CPU memory, communications protocols, strengths and challenges of the system, some recommendations have been proposed for each discussed SAS vendor company.

Another part of this thesis discuses challenge of the SAS implementation and continuous modifications. The continuous development in technology, instrumentation and sensors, IT technology causes development of automation system in order to be compatible with new technology. However, end users are mostly willing to choose the best solution rather than new or old, this makes the SAS vendor companies to develop not the solution which satisfy the new requirement but develop competitive solution. For the end user the changes in the control system give cost effect for the organizations to adopt new and latest solutions. End users have to order not only the new system but all necessary services, trainings and support. The technological progress influences the toughest challenges for the oil and gas industry, hoverer it provides successful operation, real-time data, continuous monitoring and diagnostic and immediate safe response of the system to any changes especially in critical situations.

With respect to the limitations of time and availability the results and discussions are limited to three SAS installations in NCS what could cause some errors in the recommendations. The other limitation was the source of materials due to the time limitation for the cross analysis of SAS installation in NCS was used public data provided by SAS vendor manufacturer, which could not be fully reliable ,but still can gives some knowledge regarding capabilities of each system .

6.2 Further Studies

This research has been performed based on experience and available information provided by different SAS vendors companies. In order to conduct the further studies of this topic, the gathering of information from perspectives of SAS developments and innovations could be analysed with different organizations and different geographical areas to cover the overall designs and challenges of SAS project implementation. The SAS technology improvements and modifications have no end. And the problem discussed can be done with interviewing different complex organizations not only in oil and gas business. The collection might be performed by questionnaire handling and interviewing and close work with SAS vendor manufacturer companies to collect qualitative type of information.

Chapter 7

7.1 Conclusion

This section provides the brief summary of the results and what these results can tell about. The master thesis starts with changes and modifications which were in the safety systems in NCS and what kind of demands and requirements were prerequisites for these changes. It was found out those modifications in the SAS caused by technology developments, industrial demands and by changes in the standards and requirements .The thesis provides the list of standards and requirements necessary for SAS design including the instrumentation level. This list of standards could be a good material where to get the knowledge about SAS design, instrumentation design and parameters of system and field equipment.

The important findings about SAS installations in NCS with cross analysis of technical, operational and functional characteristics could be useful during the SAS project implementation for the EPC companies. Other finding about strengths and challenges of the different SAS vendor manufacturer gives some knowledge about what is the best SAS for certain processes.

Offshore oil & gas production industry has many advanced solutions such as integrated operations, technology changes, smart operations etc. The ongoing improvements to offshore-onshore processes make a significant difference to the way of SAS design and implementation. There is chapter devoted to analysis of challenges during SAS implementation and their effect on the SAS development and implementation process.

This thesis proposes possible future developments and industrial demands for the SAS implementation and provides some recommendations for the SAS installations in NCS. These recommendations based on the current industrial demands such as: Integrated Operations, Smart operations, Wireless sensor network and Safe environment condition. These demands in the offshore oil & gas production sector have direct effects on the production profile and operational costs. The major challenge for avoiding serious events and catastrophic incidents relates to ability to employ smart technologies and techniques such as diagnostic and prognostic in order to enable early decisions and actions prior to the emergency shutdown.

Chapter 8

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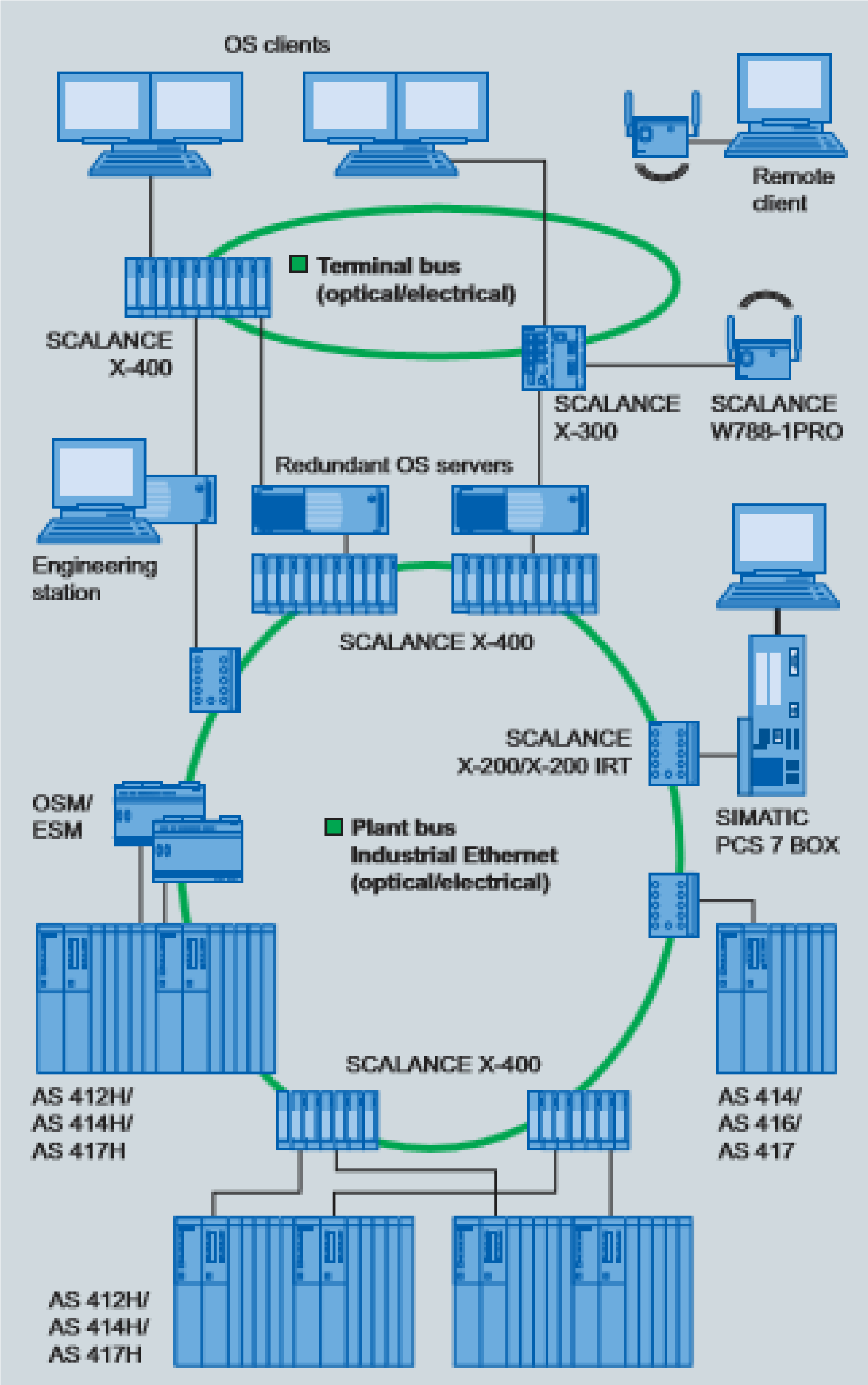
Appendix 1-1. Siemens PCS7 system architecture



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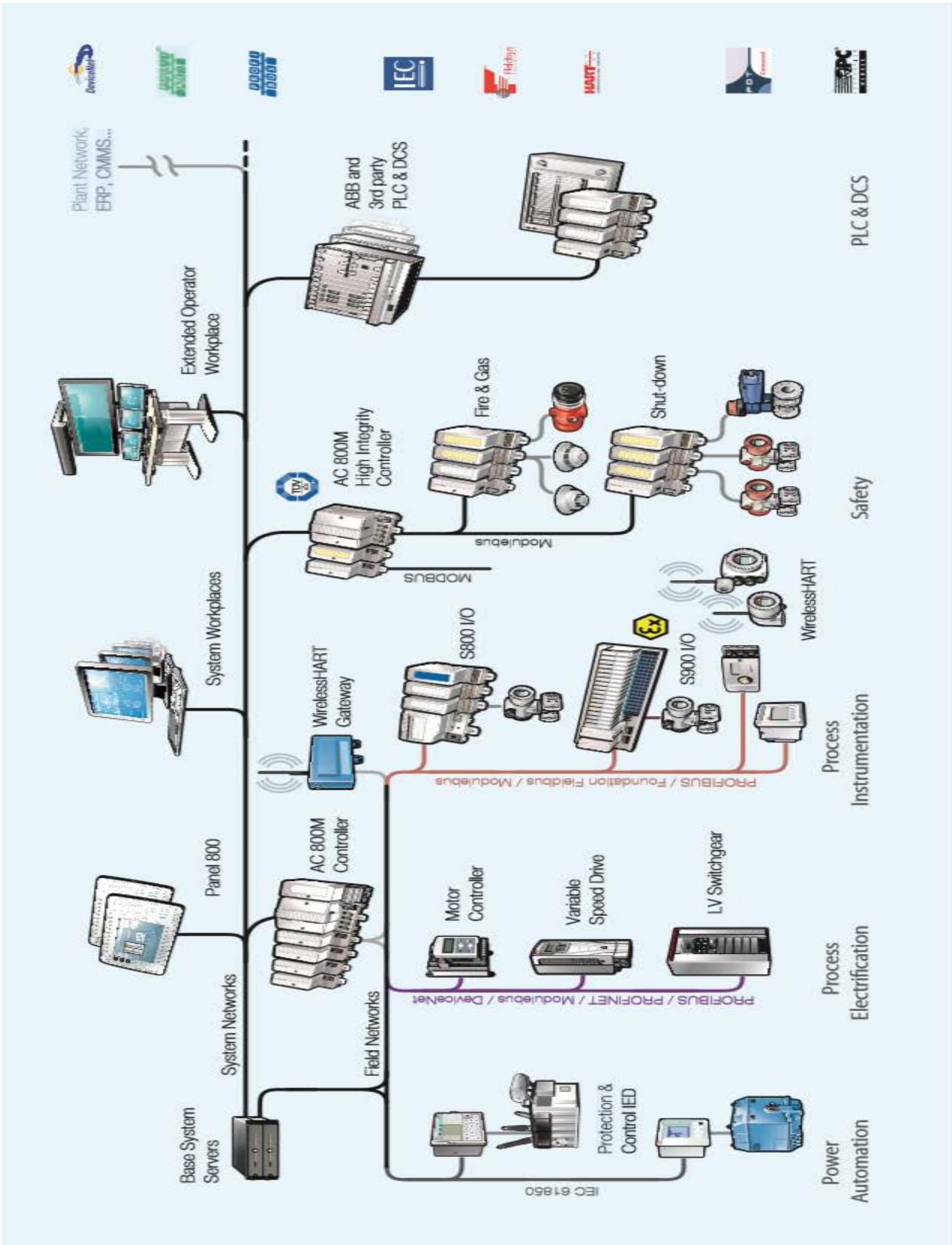
Appendix 2-1.ABB System 800xA Configuration



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Appendix 3-1.Conceptual SAS Topology

ESD = Emergency Shut-Down System

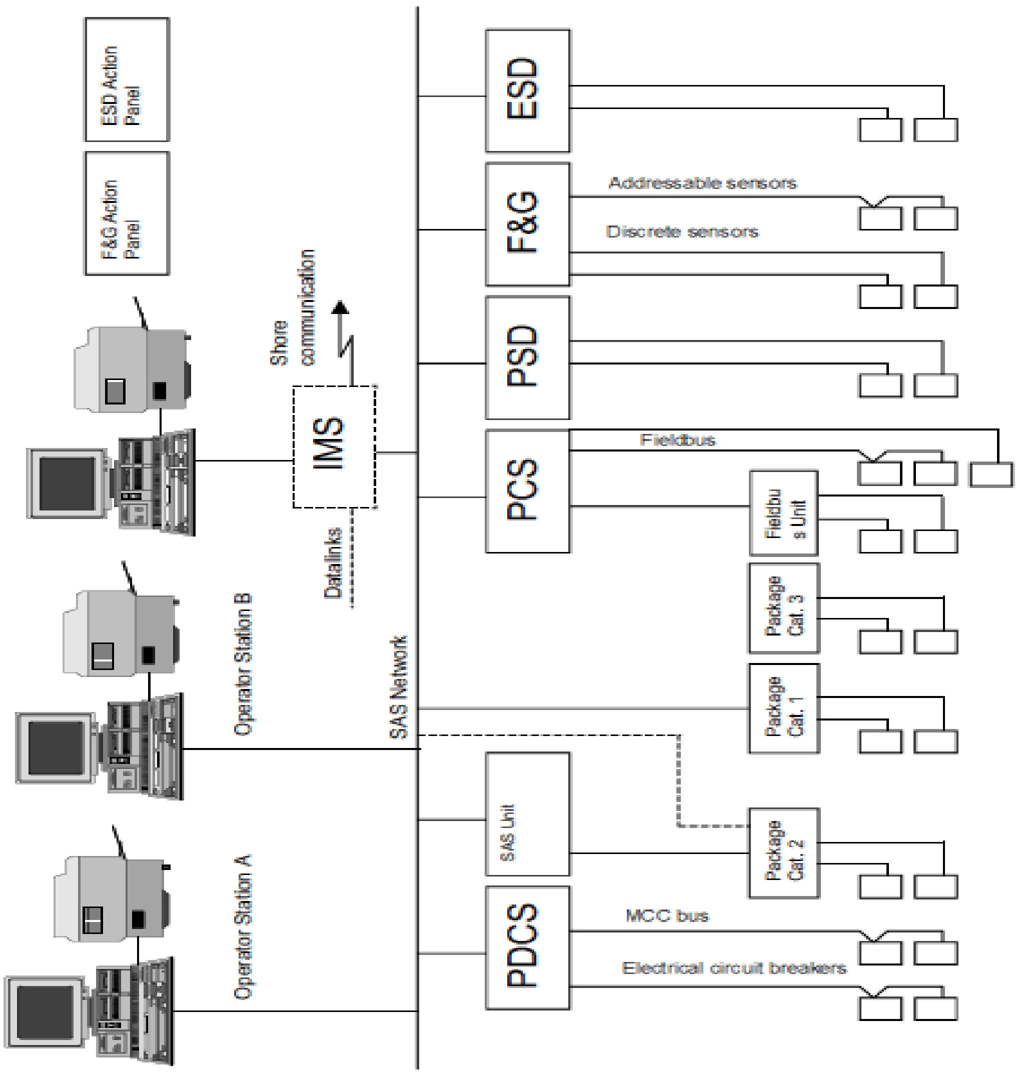
F&G = Fire & Gas System

IMS = Information Management System

PDCS = Power Distribution Control System

PCS = Process Control System

PSD = Process Shut-Down (system)



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Appendix 4-1.Experion PKS System Architecture