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HF/HMI Challenges in modern control system design in the Norwegian oil and gas industry

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At the end I love to thank my dear family for their everlasting support.

And to the memory of my father who lives in my heart, forever.

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ABSTRACT

The main purpose of this study is to observe how the teamwork between automation engineer, human factors responsible, operator and multidisciplinary design group can improve the HMI design development process in a more efficient way. The main normative standards used are ISO 11064-5, ISO 11064-7 and NORSOK I-005.

My interest for the thesis objective and delimitations has been arisen during taking part in “Human-Machine Interaction- Applications” course in 2009 at UNIK and HFS AS. The course contains undergoing human factors theory and practical exercises to apply the human factors principles, approaches and methods of analysis, design and evaluation of human-machine systems.

A part of the course is about different standards used in different industries. One of them is ISO-11064 which is relevant for the oil and gas industry. Enjoying both this course and “Technology, innovation and product development” course, in addition to the work experience as an automation engineer has been arisen my interest to find out how an automation engineer can design a better human machine interface by taking advantage of the human factors engineering methods. Moreover the concept of how the teamwork between these engineering fields and end-users involvement can lead to a better design process and product has been highly a point of interest.

This thesis includes the following main parts.

- Presentation of the problem, scope of the subject, background and the methods used through the report.

- The theoretical frame work which is a research of the articles and reports relevant for the problem.

- Presentation of a case study. The case study includes part of the HMI design in an onshore control room. Part of the process systems is described from the first step of the HMI design process until the HMI design engineering document (HMI-Sketches) are completed. The main purpose of this study is to observe how the teamwork between automation engineer, human factors responsible, operator and multidisciplinary design group can affect the HMI development process and also to map the limits of how and when this teamwork can be performed.
  The case study also includes part of the large screen display design process.

- The presentation, discussion and results of an email questionnaire to highlight the different opinions of automation and human factors engineers and specialists about questions related to the HMI design process.

- The last part of the report is the discussion and conclusion based on the literature reviews, case study, email questionnaire and the relevant standards.

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ABBREVIATIONS AND DEFINITIONS

Abbreviations

Abbreviation	Description
BCH	Terminal name(Output position high)
BCL	Terminal name(Output position low)
BXH	Terminal name(Binary status high)
BXL	Terminal name(Binary status low)
CAP	Critical Alarm Panel
CCR	Central Control Room
CCTV	Close circuit Television
CR	Control Room
DCS	Distributed Control System
DCC	Direct Contact Cooler
EID	Ecological Interface Design
ESD	Emergency Shutdown
FEED	Front-End Engineering and Design
FIC	Flow Indicator Controller
F&G	Fire and Gas Detection System
FOD	Function Oriented Displays
FV	Flow Valve
GL	Guide Line
HAZID	Hazard Identification studies
HAZOP	Hazard and Operability studies
HF	Human Factors
HFIP	Human Factors Integration Plan
HMI	Human-Machine Interface
HRP	Halden Reactor Project
HS	Hand Switch
HSI	Human-System Interface
HV	Hand Valve
HVAC	Heating, Ventilation and Air conditioning
IEC	International Electro technical Commission
IFE	Institute for Energy Technology
IGV	Inlet Guide Valve
IO	Integrated Operations
IRD	Information Rich Displays

ISO	International Organization for Standardization
LIC	Level Indicator Controller
LSD	Large Screen Display
LOPA	Layers of Protection Analysis
LV	Level Valve
OGP	Oil, Gas and Petrochemical
PIC	Pressure Indicator Controller
PCS	Process Control System
PFD	Process Flow Diagrams
PSD	Process Shutdown
PSV	Pressure Safety Valve
PV	Pressure Valve
P&ID	Process and Instrument Diagram
SAS	Safety and Automation System
SCD	System Control Diagram
TR	Technical Requirements
TIC	Temperature Indicator Controller
TCM DA	CO2 Technology Centre Mongstad DA
TV	Temperature Valve
VSD	Variable Speed Control
V&V	Validation and Verification
XU	Numbering System for Sequences(start/stop)

Definitions

An Engineering Design work programmer is concerned with the physical design and procurement of the facility. This includes the design of facility layout, buildings and other work places, operator workstations and control systems including alarms [1].

Brightness: Attribute of visual sensation associated with the amount of light emitted from a given area [7].

Control (verb): Purposeful action to affect an intended change in the system or equipment [7].

Control (noun): Device that directly responds to an action of the operator, e.g. by the operator applying pressure [7].

Control centre
Combination of control rooms, control suites and local control stations which are functionally related and all on the same site [7].

Control room: Core functional entity, and its associated physical structure, where control room operators are stationed to carry out centralized control, monitoring and administrative responsibilities [8].

Control room operator: individual whose primary duties relate to the conduct of monitoring and control functions, usually at a control workstation, either on their own or in conjunction with other personnel either within the control room or outside [7].

CRIOP: CRIOP is the leading methodology to verify and validate the ability of a control center to safely and effectively handle all modes of operations including start up, normal operations, maintenance and revision maintenance, process disturbances, safety critical situations and shut down. The methodology can be applied to central control rooms, driller's cabins, cranes and other types of cabins, onshore, offshore and emergency control rooms. The methodology is based on several standards and was in 1997 recommended as a preferred methodology in NORSOK S-002. Criop is maintained through Forum for Human Factors in Control Systems, HFC forum [11].

Digital display: display in which the information is shown in numerical code [7].

Human Factors discipline: Human Factors is a discipline of study that deals with human-machine interface. Human Factors deals with the psychological, social, physical, biological and safety characteristics of a user and the system the user is in. It is sometimes used synonymously with ergonomics, but ergonomics is actually a subset of Human Factors [19].

Human-system interface (HSI) / human-machine interface (HMI): All matters and procedures of a machine (or system) available for interaction with its (human) users [7].

Information: Anything which is not known by a person in advance, (i.e. what is new to the operator) [7].

Integrated Operations: Integrated operations involve use of information technology to change work processes to achieve better decision making, to remote control equipment and processes and to move functions and personnel to onshore. It is based on computer technology which makes it possible to transfer information without significant time delay over long distances. Personnel onshore can have the same information at the same time as people offshore. This opens opportunities to change the way of work. Various technologies and knowledge connected together which can transform task sharing between offshore and onshore, operator and suppliers (Based on ref. [20])**.**

Interaction dialogue: Exchange of information between a user and a system via the human-system interface to achieve the intended goal [7].

Life cycle phases of a process plant: Engineering, Implementation, Commissioning, Operations, Modifications [10].

Overview display: high-level abstraction, or low level of detail, of the system status, covering the areas of responsibility [7].

Process control: monitoring and manipulation of variables influencing the behavior of a process to conform to specified objectives [7].

Validation: Confirmation, through the projective of evidence, that the requirements for the specific intended use or application has been fulfilled [9].

Verification: Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled [9].

Virtual organization: Virtual organization is often defined as a group of people from different organizations located at different geographical locations working together in shared interdependent processes to achieve shared objectives within a define time frame [5].

Workload: Physical and cognitive demands placed on the system user(s) and/or staff [9].

1 INTRODUCTION

ISO 11064, "Ergonomic design and control centers" provides guidance on how the process and documentation requirements for designing a control room should be handled in oil and gas industry. ISO-11064-5 "Displays and Controls" is used for human-machine interface design which is an important part of control room design process [7].

The ISO-11064 does not only apply to the design of the work space, the work station and the work environment, but also the design of human-machine interface between the operator and the control system, with the intention of improving the effectiveness, efficiently and safety of the control process as well as optimizing the resulting workload for the operators, which in turn may influence system effectiveness, efficiently and safety [7].

The guidance given in the ISO 11064-5 includes a check list when it is about designing the pictures but does not describes in detail how the design shall be done to achieve these goals.

NORSOK I-005 is used to make the system control diagrams (SCD) in the Norwegian oil and gas industry. The SCD approach represents a structured methodology based on the development of the System Control Diagram [10]. These diagrams give an early picture of the HMI for each system.

The main objective is to observe how the teamwork between automation engineer, human factors responsible, operator and multidisciplinary design group can improve the HMI design development process. The main normative standards used are ISO 11064-5, ISO 11064-7 and NORSOK I-005.

The report is also a research about how some of the goals for HMI design included in ISO 11064-5 can be achieved through the HMI development process. Also this research tries to explore if some of the goals in the ISO-11064-5 and ISO-11064-7 can be achieved through the SCD design with focus on NORSOK I-005.

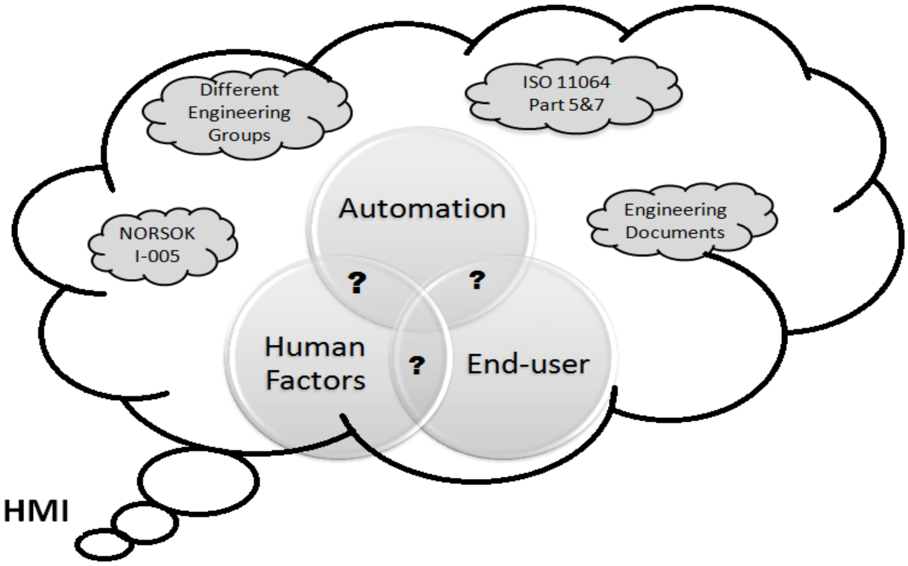


Figure 1: Summary of the problem

1.1 Research problems and questions

In practice it is always many possibilities to improve the graphics. In this work it is tried to explore the best possible way for the design of HMI in reality regarding information requirements with main focus on all the information which is needed in HMI for operators to accomplish their tasks.

The limitation of time and resources in a detail engineering project is totally different from a research project, and the cost of a project has been always an important factor for planning the HMI design process. A goal based and affective HMI design process can lead to a better product, less changes at the end of a project and less cost.

The purpose of the document is to provide an overview of the teamwork between HF, automation engineer, end-user and other engineering groups involved in the HMI development process. Automation discipline has to use different standards through the design. In reality automation discipline is the main disciplines to ensure that the safety principals and process conditions are implemented in the safety and automation systems. HF is a part of the safety discipline and has a close teamwork with automation for the design of control rooms. Part of this teamwork is the HMI design process.

There are different practices of this teamwork in different projects and the limits of who should be responsible for different part of the HMI design process is not clarified in the standards. Clarifying this limits and try to find out the best possible way to describe this teamwork has been one of the main questions for the research (Ref. Question 8, page 3) and also to describe how a good teamwork can ensure a better product and design through this report.

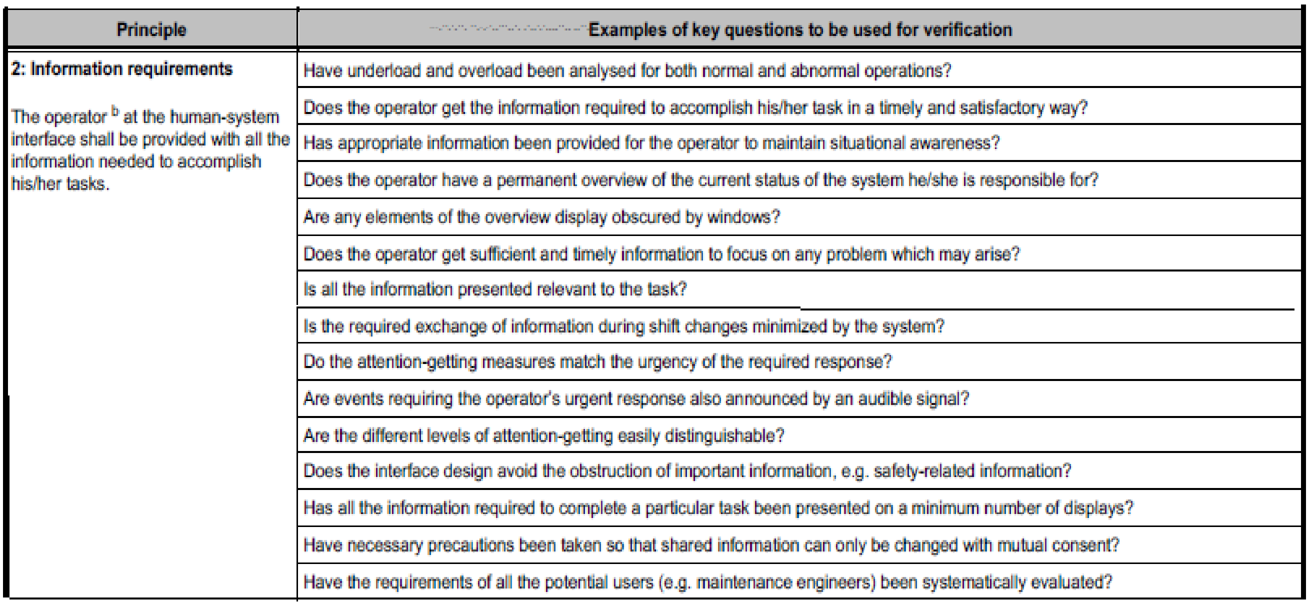
In general, the HF discipline is responsible to ensure that the goals of ISO-11064 are achieved during the control room design. Regarding to HMI design in part 5 of the ISO-11064 it has been included a check list which gives a guide line for the most important goals for HMI design in each project.

In the other side, the automation engineer is responsible for the design of logic diagrams and the software. There are many different standards that is used through the SCD design and almost all detail and critical information from P&ID, HAZID, HAZOP and LOPA is included in the SCD‘s. This critical information and special conditions which is included in the SCD‘s should be given extra attention during the HMI design for each system.

None of the standards (ISO 11064 and the Norwegian standard NORSOK I-005) takes into account the interfaces between the automation and HF discipline regarding HMI design in detail. Also there is no detail information about the engineering documents needed for the HMI design in ISO-11064(especially part 5 and part 7).

The main purpose is to map the teamwork between the two disciplines and to explore if a good team work can improve the design. By ensuring that the final product supports the operator, ensuring a systematic and effective involvement of the end-user through the design and ensuring that the normative standards and multidisciplinary design process are included in the design.

One of the cases where HF and automation have to work together is for ensuring that some of the HMI information requirements mentioned in the ISO 11064-5, included in figure 2 is achieved through the HMI design process.



Principle	Examples of key questions to be used for verification
2: Information requirements The operator ^{b} at the human-system interface shall be provided with all the information needed to accomplish his/her tasks.	Have underload and overload been analysed for both normal and abnormal operations?
	Does the operator get the information required to accomplish his/her task in a timely and satisfactory way?
	Has appropriate information been provided for the operator to maintain situational awareness?
	Does the operator have a permanent overview of the current status of the system he/she is responsible for?
	Are any elements of the overview display obscured by windows?
	Does the operator get sufficient and timely information to focus on any problem which may arise?
	Is all the information presented relevant to the task?
	Is the required exchange of information during shift changes minimized by the system?
	Do the attention-getting measures match the urgency of the required response?
	Are events requiring the operator's urgent response also announced by an audible signal?
	Are the different levels of attention-getting easily distinguishable?
	Does the interface design avoid the obstruction of important information, e.g. safety-related information?
	Has all the information required to complete a particular task been presented on a minimum number of displays?
	Have necessary precautions been taken so that shared information can only be changed with mutual consent?
	Have the requirements of all the potential users (e.g. maintenance engineers) been systematically evaluated?

Figure 2: General principles [7]

There is some example of key questions in figure 2 which should be used for verification of HMI regarding information requirements.

It is very important to have an overview of the plant for being able to plan best possible design process for HMI in each project. However to specify and structure the work the following research questions are made:

1. How can the designers ensure that the operator has a permanent overview of the current status of the system they are responsible for (Based on original question in [7])?

2. How can the designers ensure that the required exchange of information during shift changes minimized by the system (Based on original question [7])?

3. How can the designers ensure that the requirements of all potential users (e.g. maintenance) been considered (Based on original question in [7])?

4. How can the designers ensure that all the information presented is relevant to the task (Based on original question in [7])?

5. How can the designers ensure that all the information required to complete a particular task been presented on a minimum number of displays (Based on original question in [7])?

6. Why is the LSD used in control rooms and how can the LSD help the operator?

7. How can the HMI design process be described from the Process Flow Diagrams to the final human machine interface? (With main focus on process information requirements)

8. How can the teamwork between HF, automation, end-user and other engineering groups affect the HMI design process more positive?

1.2 Limitations

There were many points mentioned in the ISO 11064-5 that attracted my attention at first. After a while the report's main topic directly linked to the part 5 is the questions mentioned in chapter 1.1 with main focus about information requirements and affects of the teamwork between the different engineering groups involved in the multidisciplinary HMI design process.

The report does not take into account the graphic element presentations of the HMI, ergonomic part of the HMI design and not any cases about alarm system or alarm management. And also the main focus is about the process pictures and the work does not include other type of pictures such as electro or HVAC.

2 METHODS USED

There are three main methods used in this work to find out the answer for the eight questions mentioned in chapter 1.1. First part is literature review, then a case study and at the end an email survey. Figure 3 illustrates a summary for this report.

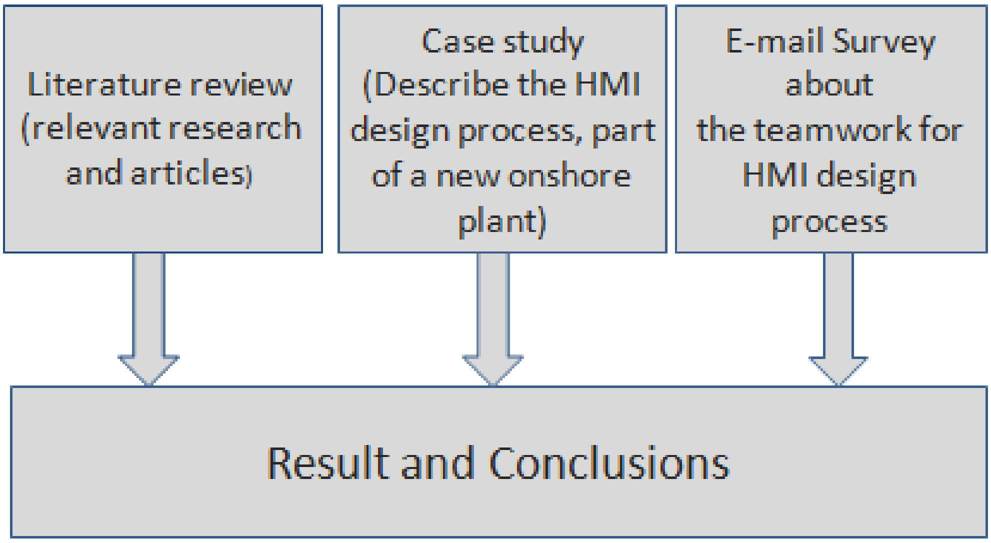


Figure 3: Summary of the methods

Literature review: Through the literature review the author has tried to map the results of different researches both from Norwegian and international researches/articles.

Case study: There is included one case study in this research. Part of the HMI design process of a project has been described in detail.

Participation and observation: Case study in this report includes participation and observation methods through the design of the HMI. The author is the automation engineer responsible for the SCD design, responsible for part of the HMI design philosophy and HMI development process, also has been part of the multidisciplinary design team for the design of HMI in a period of more than two years.

E-mail survey: An E-mail survey which has been answered by 24 Automation engineers and HF specialists.

Also the following human factors engineering evaluation methods which have been relevant for an automation engineer involved in HMI design process has been used during the case study.

Brain storming: At the start of HMI designed for the different parts included in the case study, the basic scope was decided by use of brain storming method when all participants came up with different ideas. This method helped a lot for the responsible designer to design different concepts which gives freedom to the operator to choose the best ideas related to the operator task.

Prototyping: Prototyping or sketching has been used in the case study. It is described later in this report that how this simple and the same time important method can help the HMI design process results.

3 SHORT INTRODUCTION OF NORMATIVE REFERENCES

3.1 Short Introduction ISO 11064-5 and 11064-7

ISO 11064 consists of the following parts, under the general title *Ergonomic design of control canters:*

Part 1: Principles for the design of control centers
Part 2: Principles for the arrangement of control suites
Part 3: Control room layout
Part 4: Layout and dimensions of workstations
Part 5: Displays and controls
Part 6: Environmental requirements for control centers
Part 7: Principles for the evaluation of control centers

Part 5 of ISO 11064 presents principles and processes to be adopted when designing the human-system interface of a control centre [7]. Part 7 describes the principles to be used for the evaluation of the control centers [9].

These interface considerations are relevant for operators, supervisors and maintainers of systems. It is intended for use by individuals such as project managers, purchasers, systems designers and those developing operator interfaces [7].

The purpose of ISO 11064-5 is to maximize the safe, reliable, efficient and comfortable use of displays and controls in control centre applications [7].

It has been mentioned in the ISO 11064-5 that the design results shall be evaluated during each of the design steps described in figure 4. For this purpose, it is recommended in the standard that early sketches, prototypes, and mock-ups be applied for each step.

During this report it has been tried to find out the affects of using prototyping/sketching method in the early phase of the HMI design process and also to find out if using this method can results to a better presentation of information for each HMI or not.

Generally in part 7 of the ISO 11064 [9] for V&V issues has been mentioned that the V&V activities shall be an integral part of the design process and the tests shall be done as early in the design process as possible.

Human system interface software is part of the scope of V&V activities for a control center [9]. Also in the ISO 11064 -7, the general requirements and recommendation for evaluations process is mentioned but the timing of V&V activities is not specified.

In one of the informative parts of ISO 11064 -7 has been included that it is difficult to find guidance on when in the design V&V is best applied [9]. In this report one of the challenges has been to find out more about the timing of V&V activities and the evaluation methods for these activities.

Later in the report, the affects of some of this HF evaluation methods and the time of V&V activities is more discussed.

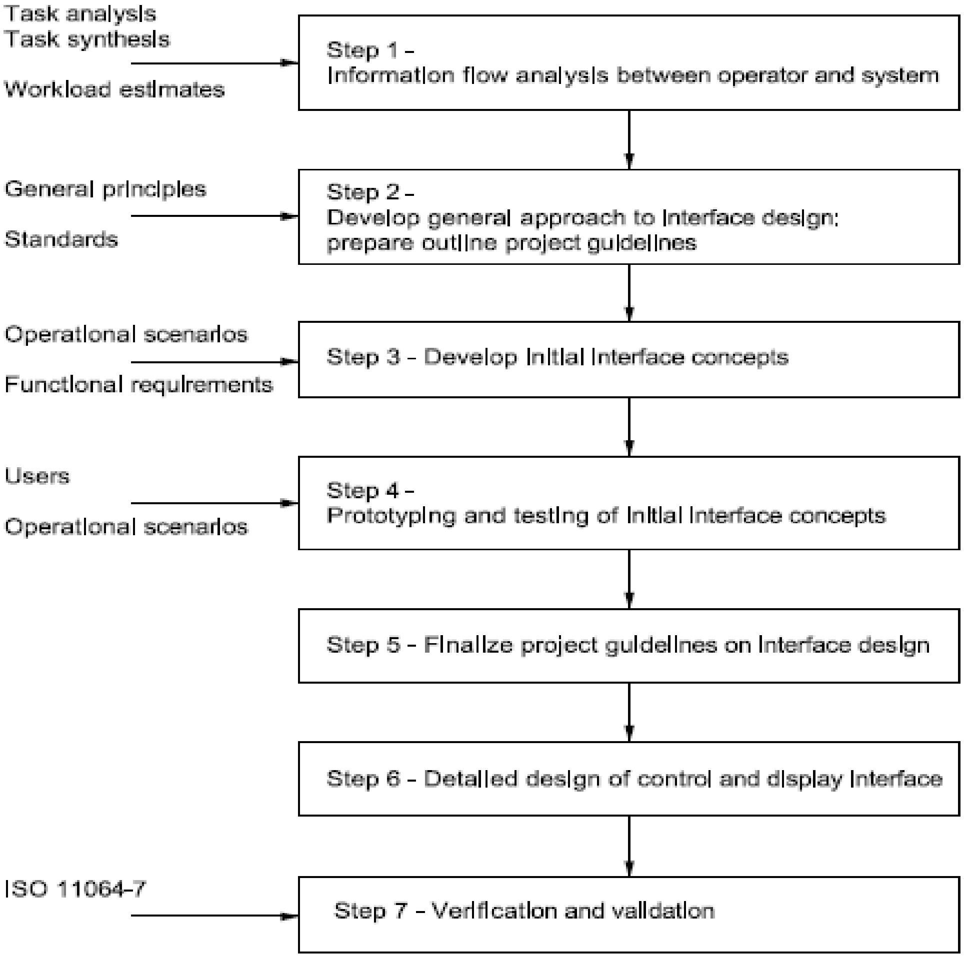


Figure 4: Process for display and control specifications [7]

3.2 Short introduction NORSOK I-005

The system control diagrams (SCD) drawings are based on the standard NORSOK I-005. The NORSOK standard [10] are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are as far as possible intended to replace oil company specifications and serve as references in the authorities' regulations.

The success of a plant development project depends on good and efficient means of communication between the involved parties, during all phases of the project [10].

Present extensive use of computerized systems and 3D modeling provide efficient tools for specifying and handling of physical equipment in a standardized manner [10]. However, the development of methods and tools to specify functional relationships has not reached a corresponding level [10].

During the plant development the process engineers specify the process through the development of the P&IDs. Throughout this work process the process engineers acquire a thorough understanding of the total plant behavior [10]. However, the P&IDs provide limited facilities for documentation of the overall functionality as well as operational aspects of the plant [10].

It’s the control system engineer's task to design the control system so as to fulfill the process functionality required to achieve product specifications as well as the requirements imposed by the overall operating & control philosophy and manning levels [10].

To conserve the functional relationships implicitly specified by the P&IDs, the control system engineers have to transform the process engineer’s imagination of plant behavior into the control system design and implementation [10].

The operator's evaluation of the operational efficiency of the plant is a difficult task without any proper documentation of the overall control and monitoring functions available. Often, operational problems within the different systems can not be identified until the system is in operation, leading to major modifications in late project phases in the worst case [10].

In-depth system knowledge is required to understand both the available functions as well as their interconnections [10]. There is no intuitive link between the control system functions and their interconnections, and the process flow itself. The interactions between the process and the control functions are identified through single tags only [10].

Due to the missing link between the functions implemented in the control system and the P&IDs defining the process flow, the process engineer’s possibility to verify that all process aspects have been properly catered for in the implementation of the control system is very limited. SCD‘s are the missing link between the P&ID‘s and the control systems functionality [10].

In this report it is tried to find out about the missing link between the SCD‘s and the HMI, and to show the importance of a good quality of SCD’s as one of the documents used for V&V of HMI can affect the whole HMI design process early in the design.

4 LITERATURE REVIEW

Automation has improved safety, comfort and job satisfaction in many applications; however, it can also lead to many problems. Careful design that considers the role of the end-user can help avoid these problems.

Frohm (2008) in his doctoral theses [13] "Levels of Automation in production systems" has mentioned that increasing levels of automation in unforeseen production situations can be related to production disturbances. The human operator that can handle those unforeseen situations does not always have the ability to interpret present and future production situations, based on available information from the production system [13].

The author [13] also includes that automation can create both low and high workload extremes. That high levels of automation can leave the operator bored can perhaps be understandable, but that automation can increase e.g. the cognitive workload is one of the "ironies of automation", according to Bainbridge (1982). Automation was initially employed to decrease the workload during normal operations [4]. Ironically, the technology that aimed to give conceptual simplicity also seems to decrease the sense of direct control in the actual work situation [13].

According to "ironies of automation" [14] the increasing availability of soft displays on VDUs raises fascinating possibilities for designing displays compatible with the specific knowledge and cognitive processes being used in a task. This has led to such rich veins of creative speculation that it seems rather mean to point out that there are difficulties in practice.

In many situations automation supports human decision making, but the challenges of creating useful automation will become more important [14].

In this part some relevant results from articles which have discussed the ISO 11064 regarding end-user involvement, the HMI design process and the importance of team work between different engineering groups and human factors engineers through the HMI design is included. The main research words have been ISO 11064, HF, HMI and HSI.

4.1 Experiences of applying the ISO-11064 in practice

ISO 11064 part 5 and part 7 are the main international standard for HMI design in the oil and gas industry. These two parts of the standard contribute to a goal based HMI design process and also presents the main criteria's for validation and verification of the HMI product.

Aas *et al.* (2007) in their article [5] summarize experiences made when applying ISO 11064 in Norwegian petroleum projects and suggest areas for improvements. Their research doesn't discuses part 5 and part 7 of the standard but their conclusions helps the engineers to understand the important affects of the standards regarding control room design.

The main objective of their study has been to map experiences from applying ISO 11064 to control center design in full scale industrial projects. Their paper is based on semi-in structured interviews with persons from the Norwegian petroleum industry [5].

The result of the article includes strengths and weaknesses of the ISO 11064 and CRIOP, summary of their discussions and their results.

The authors [5] identify the following strengths for the ISO 11064. The authors [5] conclude that the standard gives a good and structured methodology for the process of control centre design. They [5] mention that the participants had agreed that the process described in the standard's part one gives reasonable overview of the phases and thus provides teamwork in which to conduct the required HF activities.

The other strength points in their point of view [5] have been the interdisciplinary design team. Part 1 of ISO 11064 contains nine principles of ergonomic design. The principal number eight “Form of interdisciplinary design team” is considered to be a very effective tool in the design process. Disciplines in the interdisciplinary design team can be, but are not limited to instrumentation and automation, operations (including experienced CC operators), occupational health and safety, architect, telecom and HF [5].

The article includes that when the facilitator of the interdisciplinary design team is a HF expert , it was noted that it ‘s very important that he or she has a good understanding of the projects technical and organizational aspects, oil and gas operations and is able to communicate effectively with the rest of the team. This includes understanding the technical terms [5].

The authors [5] also identify the following weaknesses for the ISO 11064.

One of the weaknesses in their [5] point of view is the scope of ISO 11064. In their paper, ISO 11064 is concerned with the design of CCs. The definition of the CC is “combination of control rooms, control suites and local control stations which are functionally related and all on the same site” [5]. This definition of CC may conflict with the ideas behind IO.

IO may lead to remote support or remote control and remote operations of platforms offshore [5]. Issues such as responsibility, communication, command and control is increasingly important in such work.

The other weakness mentioned in the article [5] is organizational issues within the CC. The article discuss that the standard doesn’t clarify the challenges for remote operation, integrated operation or virtual organizations. The author’s opinion is that the standard should support IO and virtual organizations and the use of distributed control centers and collaboration rooms, to help improve and guide HF in these new settings [5].

Another point in their point of view [5] is organizational issues in the project. The processes of ISO 11064 were said to be ‘out of sync’ with the rest of the project but they conclude that this problem can be solved by adopting the use of the standard to each project [5].

4.1.1 Potential improvement of ISO 11064

In this part of the article [5] the authors discusses several potential improvements of the ISO 11064 which have been identified by their work. Some of their suggestions which are relevant for this report are included in this chapter.

One of the points the article discusses is about HF activities. These activities should aim at satisfying engineering needs [5]. Then the processes in ISO 11064 will become better synchronized with the project processes. I.e. instead of just doing a function analysis and allocate functions to human and/or machine, it’s more appropriate assist engineers in understanding the way operators actually operate the system [5]. Still, HF personnel must identify all major HF issues before design freeze to avoid potentially hazardous design solutions [5].

The issues related to user participation during the design are another point discussed in the article. The fact that operators can be unavailable early in a project raises serious challenges of the user participation [5] in their point of view. Principle seven in part one of ISO 11064 is “*Ensure user participation*”. This becomes a problem when there are no users available [5].

Another potential improvement that the authors [5] have discussed is the competence requirements. They include that having an appropriate person taking care of the HF aspects is a critical success factor and ISO 11064 has established that HF competence must be incorporated into a project. Both Oil & Gas operators and engineering companies often hire external HF consultants to implement the principles of ISO 11064 (and other standards/regulations) into the design [5]. ISO 11064 should, in addition to establishing HF competence, include requirements that HF personnel have at least a basic knowledge of the type of system the CC is designed for, or to obtain this knowledge before starting the work [5].

4.2 The importance of end-users participation during the design

Cullen (2007) in the article [1] has discussed the gap between system designers and end-users. During 2004, the author [1] facilitated the integration of HF into a development project being implemented at a gas processing facility on mainland Britain. This article has provided information on this process and the benefits it provided to the operator. This topic can help the engineers to understand the affect of why HF shall be involved actively during the CR design process and HMI design process.

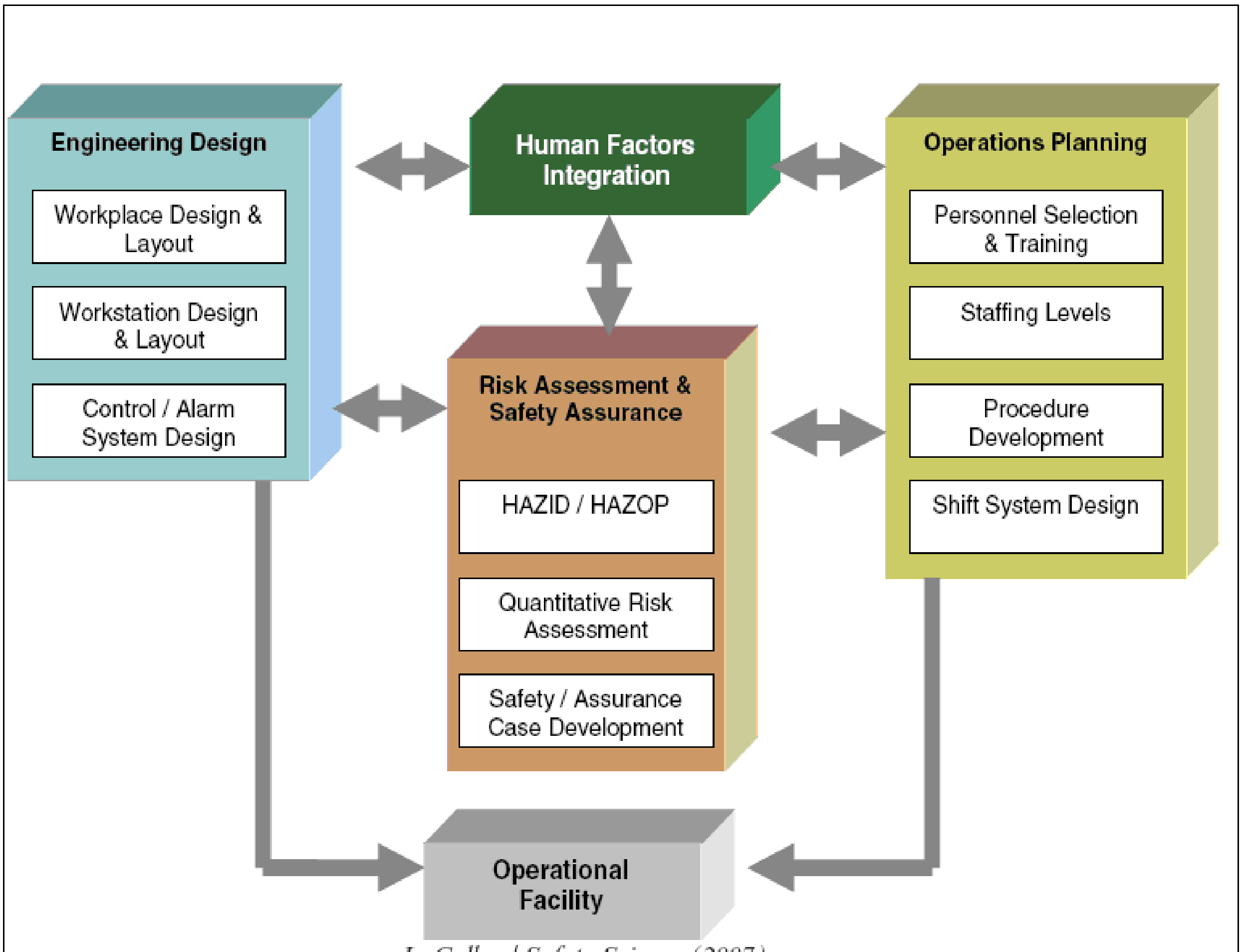
The article [1] includes that one way in which this potential gap can be bridged is to formally involve end-users or operations representatives in the project teams. This is increasingly commonplace in large projects and encourages design engineers to consider the people who will operate within the system being designed in terms of who they are and what tasks they will be performing [1].

However, whilst operations representatives will have the necessary knowledge of how the facility will be operated and maintained, and some experience of issues concerning usability, they do not have a specialist and objective understanding of human capabilities and limitations [1]. It is important that the system designers take account of these in design to avoid exceeding limits of human performance [1]. Consequently it is beneficial to integrate human factors into projects to guide the design and help strengthen the bridge that operations representatives provide between system designers and end-users [1]. Figure 5 in the next page illustrate the project major work streams with HFI.

In the article [1] is mentioned a chemical company as an example. A chemical company would not design a new plant without chemical engineers, electrical engineers and other discipline experts. Likewise, it is necessary to include within the project team a ‘human’ engineer, i.e., an individual with sufficient knowledge of human capabilities and tolerance limits [1]. This helps ensure that engineering design work takes account of end-user requirements, and that operations planning reflects the emerging facility design [1]. In a typical project, human factors support can be provided to the many aspects of the engineering design, operations planning, and risk assessments [1].

Author [1] includes that one of these aspects is Human–machine interface (HMI) design, including alarm, to ensure that operators are provided with the appropriate information/displays and controls required to undertake tasks, and that these are presented and laid out in an appropriate manner. This aspect is particularly important for safety critical tasks such as those associated with degraded/upset upsets, where a good interface is required to support the operator in detecting, diagnosing and responding to problems [1]. Failure to consider HF in HMI design can result in a non-user-friendly system that is difficult and potentially unsafe to use. Issues covered include text size, color usage, screen density and layout, and symbols [1].

The authors [1] mentioned that the work carried out to prepare the HFIP (human factors integration plan) in their work identified a number of areas where further consideration of end-user requirements and HF was necessary. The article [1] includes there were some areas where a gap was emerging between the designers and end-users. Specifically, the DCS design had failed to accommodate operational requirements, thus highlighting a gap between end-users and designers [1]. The main issues raised were as follows: alarm priority names, color coding, process graphics, new symbols and labels.



L. Cullen / Safety Science (2007)
Typical project major workstreams with human factors integration.

Figure 5: Project major workstreams with HFI [1]

The conclusion of the article [1] is that without HFI, system designers and end-users may not have an adequate understanding of each other's requirements [1]. If a project proceeds on this basis, with engineering design and operations planning being insufficiently integrated, the project may deliver a facility that has operability problems and hence potential reliability and safety concerns [1].

4.3 HF role in PCS design

Friedhelm *et al.* (2006) in their article [2] deals with selected problems of human factors in the design of process control systems. Authors include that their practical experience shows that human factors is not taken into account adequately and sufficiently during PCS design.

In designing operator–system interfaces in process control systems two different but interrelated interfaces must be distinguished based on the article [2]: the *task interface* and the *interaction interface*.

Designing the task interface means [2] allocating functions to the operator and/or to the technical components of a process control system. From an ergonomic perspective this should result in tasks for the operators which they can perform safely and efficiently, without any damage to health or any impairment to wellbeing. This requires, first of all and among others, solving problems of adequate degrees of automation, which must not result in left over tasks for the operator; i.e. tasks which cannot be automated or at least not at reasonable costs [2].

The authors include to enable the operator to perform the assigned tasks safely and efficiently will usually require an analysis of goals, functions, tasks and required activities, and a subsequent analysis of the information required for an effective and efficient task performance, since only a suitable design of the displays and control actuators of the process control system will enable the operator to perform the assigned tasks without compromising operator health, wellbeing, and efficiency as well as system effectiveness, efficiency, safety, and reliability [2].

The article conclusion [2] is that according to their experience human factors do not play the role they deserve in the design of process control systems (exceptions acknowledged), making them less controllable than they could be if human factors were adequately incorporated. It would thus seem that incorporating ergonomics in the design of process control systems offers a lot of opportunities for improvements with regard to system effectiveness, efficiency, reliability and safety [2]. As a consequence it would seem that there is a clear demand for action incorporating human factors in the design of such systems right from the beginning, as already recommended by international ergonomics standards [2].

The article [2] concludes, there is a quite substantial demand for future research regarding problems of human factors in process control design. According to their experience [2] this would require cooperative joint research ventures among process control engineers, computer science specialists and human factors specialists, in order to reach a common understanding of the problems and to develop effective research strategies for designing process control systems which make full use of technical and human resources and avoid the pitfalls of single sided solutions [2].

4.4 The use of simulator for Human-system interface design

In ISO 11064 part 7 [9] different type of prototyping is presented for validation and verification of HMI. One of the most effective tools in that matter is use of software simulator in my point of view. This tool is an expensive tool which maybe is not possible to use in the projects but this chapter give a presentation of how affective this tool is for validation and verification of HMI. The main topic in the article [3] presented in this chapter is safe operation of nuclear power plant but the result is relevant for all type of plants.

Technology plays an important role in advanced control rooms that relies on complex technical equipment and interface [3]. Human error has many causes such as performance shaping factors, organizational factors and interface design. In the safe operation of nuclear power plant, the performance of the control room crew plays an important role [3]. In this respect, a well-designed control room and human–system interfaces are crucial for safe and efficient operation of the plant, reducing the occurrence of incidents, accidents and the risks of human error [3]. Therefore, it is essential that the interfaces design must be conducted in a well-structured way, applying human factors principles in all phases of the control room life cycle[3].

Santos *et al.* (2008), in their article [3] presents an approach to design the HSI for a nuclear reactor control room simulator. They mention that requirements for a human factors program will depend upon the human factors team qualifications and experience, and on the number of human factors inputs, which has been identified as necessary. The following elements are recommended to be included in this kind of program: operating experience review, functional requirement analysis, functions allocation, task analysis, staffing qualification, human reliability analysis, HSI design, procedure development, training, human factors verification and validation (NUREG 711, 2002).

The paper [3] includes that each one of these elements must be included in the life cycle of a control room design: conceptual design, detail design, construction, commissioning, operation and decommissioning. The main contributions of HFE program are to ensure that the operator tasks are clearly specified, the number of staff, their functions and qualifications are adequate, the HSIs, procedures and training meet task performance requirements and are consistent with human cognitive and physiological characteristics [3].

In their research [3] the main objective has been to obtain data using a methodological framework centered in the evaluation of the existing interfaces, and use these data in the design of the new interfaces. Their [3] framework includes tasks description, integrated evaluation of the existing interfaces, development of the new interfaces and integrated evaluation of the new interfaces. The methodology in their research [3] is schematically shown in Figure 6.

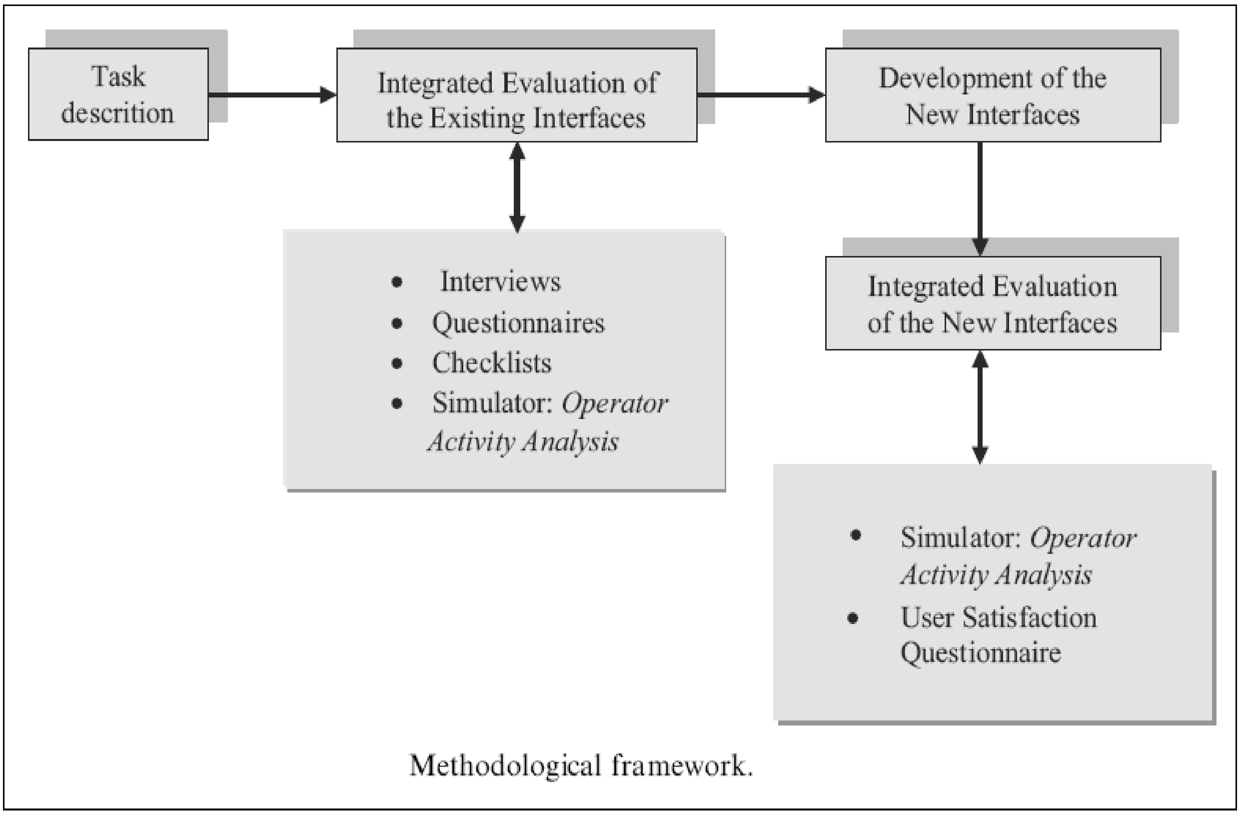


Figure 6: Methodological framework [3]

The article's conclusion [3] is based on the results from checklists, operator activity analysis and questionnaire for user-interaction satisfaction. The checklists comparison of the existing systems interfaces and the new systems interfaces shows that YES percents related to the new interfaces are greater than in existing interfaces. It shows that the new interface design satisfies a group of human factors requirements (NUREG 700, 2002).

They include [3] that the results allow them to conclude that with the new interface design based on their HFE program the operators spent less time to identify the type of design basis accident and that the navigation among the new interfaces has been optimized and the questionnaire results show that the new interfaces reached a good satisfaction level.

Their integrated evaluation of the new interfaces shows [3] that the operator activity analysis associated with human factors standards, human factors guidelines, checklists, interviews and questionnaires can be used as a support tool to the redesign of the advanced interfaces [3].

The authors [3] conclude that it is needed systems that support actions of human operators, and their ability to adapt and to adjust to novel situations. According to the article conclusion, systems must be designed considering that the user and the usage of the system need to be taken account into all the phases of the design process [3].

4.5 Research on Human System Interface

There are different ways to understand the end-users tasks during design of the HSI's. So far in this report the focus has been on the affect of teamwork between different specialties, HF and end-users involvement during the design. But in this chapter a short presentation of different type of their approaches [6] for HSI design is presented to highlight that maybe the traditional P&ID type display shouldn't be allowed to be designed anymore!

Braseth *et al.* (2009) in their paper [6] discuss and present different approach for HSI design. Innovative Human System Interfaces (HSIs) has been a major topic of their research of the international Halden Reactor Project (HRP) [6]. Based on the article different design concepts have been addressed and prototypes have been implemented and evaluated in the experimental control room facility. Many of their concepts go far beyond traditional P&ID type displays, and utilize advanced computer graphics and animations. Their paper [6] briefly has described some of the concepts, their advantages and disadvantages experienced through evaluations and feedback from user [6].

The goal of their project [6] has been to provide the nuclear industry, i.e. utilities and vendors, with knowledge and ideas for improving information presentation in hybrid or fully computerized control rooms. They have achieved the goal by designing prototypes which is implemented in full scope nuclear simulators, evaluating them in user tests and larger-scale experiments in a full scale man-machine laboratory [6].

The paper [6] summarizes the main idea of Task-based interfaces, Ecological interfaces, Function-oriented interfaces. The main idea of the task-based approach is to design displays that provide operators with all information needed to perform a certain pre-defined task as effectively and safely as possible [6].

Their Ecological Interface project [6] aimed at guiding the development of user interfaces that support rapid perception and correct interpretation of process data, especially when dealing with abnormal and/or unfamiliar conditions. Their research [6] on smaller scale processes has indicated that ecological interface displays leads to innovative new designs with the ability to improve operator performance and situation awareness in such potentially hazardous situations [6].

The overall purpose of the function-oriented displays described in their article [6] has been to reveal strengths and weaknesses of a design philosophy tentatively called Function-Oriented Design (FOD). FOD uses a function analysis of the plant as the backbone for designing an integrated computerized HSI. It is quite common to use function analysis to define information requirements for HSI design, it is for instance recommended by NUREG-0711, so this is not a unique characteristic of FOD. The uniqueness of FOD based on the article [6] is the way functions are explicitly represented through the displays and the way all parts of the HSI are designed from the same functional perspective [6].

4.5.1 Large Screen overview

Braseth *et al.* (2009) in their paper [6] discuss Large screen displays (LSD).LSD can also be referred to as "group view displays", these interfaces are typically designed to support shared situation awareness in the main control room [6]. The article includes that the Halden Project

[6] and its mother institution, The Institute for Energy Technology (IFE), has done extensive work on such displays over a number of years ranging from small overview displays to ultra-large ones.

Currently, IFE's experience in this field is put into practice in various industries ranging from the oil & gas industry, to paper manufacturing, power grid operations, as well as the nuclear industry [6]. These industries are all making the shift from traditional analogue control systems to computerized ones, increasingly experiencing the need for shared overview information [6]. Based on the paper [6] the different large-screen display concepts that have been explored have many common characteristics:

- *Visual patterns for efficient recognition. The IRD concept and other "advanced displays" have explored the potential for synthesizing information into visual forms supporting pattern recognition, especially for early detection of deviating plant states [6].*
- *Layered color scheme: Colors are chosen to form differentiable layers of information (background/static layer, focus layer and alarm layer) to effectively convey large amounts of information and direct attention [6].*
- *Dedicated zones supporting different tasks. A large screen display may have a layout supporting different operator tasks in different places, either for different plant states different type of work or roles. Examples are process overview zone, alarm zone and safety zone [6], refer to figure 7.*

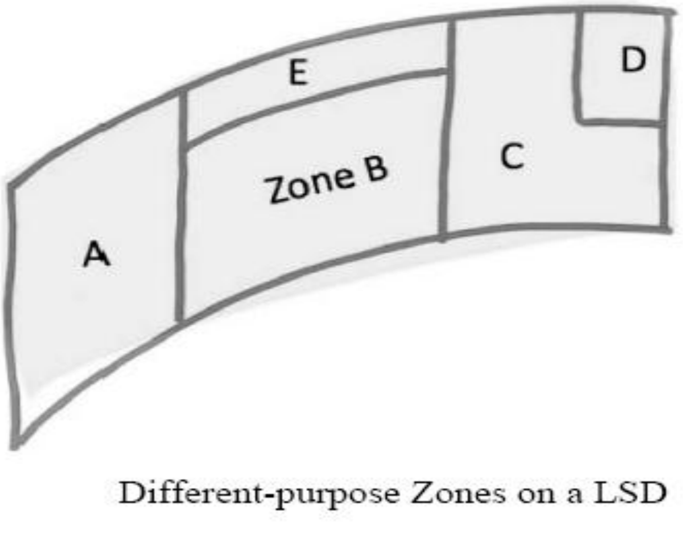


Figure 7: Different process zone [6]

The paper [6] presents a concept called information reach display design which is more presented in chapter 4.6. Their IRD concept refers to data displays that combine a grayish and low contrast color principle with analogue normalized integrated trends to obtain high data density displays without causing information overload, and at the same time provide a display where abnormal situations with alarm colors are easily detected [6].

The IRD design is patented by IFE [6], and is currently becoming the reference design standard for Large Screen Displays for Norwegian oil and gas installations [6]. The IRD design differs from traditional design in several aspects; one of the main features is the extensive use of analogue information presentation. With appropriate design, a group of objects with such properties will appear to the visual system as one single object that can be processed reliably and efficiently, avoiding operator information overload [6].

Helping operators keep the "big picture". The control room crew's process overview and situation understanding must be maintained in a computerized control room [6]. Based on the article [6] their research shows that the keyhole effect in computerized solutions can be overcome by adding meaningful information to traditional P&ID based interfaces:

- Introducing a large screen overview display (LSD) [6].
- Introducing overall information on functional and physical features related to whole or part of the system [6].
- Design interfaces that support pattern recognition [6].

The article [6] includes that pattern recognition should be supported as much as possible, i.e. control room operators should not need to use their mental capacity in reading and interpreting lots of digital numbers or other elements to understand the situation. Utilizing the computers' graphical capabilities when developing animated visualizations may reduce the mental workload and help operators detect anomalies early [6]. Applying a thoughtful color palette to differentiate between different types of information and to direct attention is considered effective based on their project results [6].

4.6 Information Rich Display Design

Braseth *et al*. (2004) in the article [12] present a new way of LSD design called "IRD". Authors mention that the purpose of Information Rich Design is to condense existing information in process displays in such a way that each display picture contains more relevant information for the user. Compared to traditional process control displays, this new concept allows the operator to attain key information at a glance and at the same time allows for improved monitoring of larger portions of the process. This again allows for reduced navigation between both process and trend displays and ease the cognitive demand on the operator [12].

Their concept [12] is based on weighing and classifying the relevance of types of information presented to users. By using well-proven principles from graphical design it visualizes this information in a manner that reflects its relevance. The IRD concept can supplement and complement other design concepts that are innovative in terms of their information content and/or visual form [12].

Their concept [12] is based on weighing and classifying the relevance of types of information presented to users. Through deemphasizing less relevant display items it becomes possible to create displays with high information density that at the same time are easily readable. The IRD concept can supplement and complement other design concepts that are innovative in terms of their information content and/or visual form, such as Ecological Interface Design and Function Oriented Design [12].

The article concludes that in they have tried to look behind the traditional ways of improving existing display formats and instead have attempted to create a new design based on user requirements [12]. To do this, they [12] have created a simple conceptual model of how an operator's focus, capabilities and limitations vary between the different roles that he/she is expected to fill in the control room under different circumstances.

5 CASE STUDY

5.1 General description

The case study includes part of a project which has been a new onshore plant. The reason of using this project as a case study is that I had the opportunity to be part of and observe the HMI design process during the FEED and detail engineering.

Even though this project is not directly typical Oil and Gas project, but all the relevant standards and procedure regarding safety and instrumentation for a typical Oil and Gas plant has been used for this project. Also the ISO 11064 and NORSOK I-005 have been used in the case study.

As mentioned the scope of the project is a total new plant which means that there has been no similar control system to be used as an example. This can help to map the challenges between HF and automation teamwork in the better way comparing to a modification of an existing control room. Because in a modification of an existing CR there is a lots of information and existing HMI which has been used and the end-user resources are available for the modification project. But in this case study the team had to start from FEED phase without enough information about the systems and also SCD‘s from FEED part of the case study for a total new plant is not sufficient to be used regarding to map the complexity of the whole plant.

This case study includes part of the Large Screen Design process and one of the main processes/systems for this plant. The process system which is going to be described in detail is a typical utility system called Flue Gas system. Refer to the reference number [22] for detail regarding project documents used for the case study directly or indirectly.

5.2 Introduction to the relevant engineering documents

5.2.1 Introduction for Process flow diagram (PFD):

PFD is a diagram commonly used in chemical and process engineering to indicate the general flow of plant processes and equipment. The PFD displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations. Typically, process flow diagrams of a single process system will include the following:

1. Process piping
2. Major bypass and recirculation lines
3. Major equipment symbols, names and identification numbers
4. Flow directions
5. Control loops that affect operation of the system
6. Interconnection with other systems
7. System ratings and operational values as flow, temperature and pressure
8. Composition of fluids

Process flow diagrams generally do not include:

1. Pipe classes or piping line numbers
2. Process control instrumentation (sensors and final elements)
3. Minor bypass lines
4. Isolation and shutoff valves
5. Maintenance vents and drains
6. Relief and safety valves
7. Flanges

Process flow diagrams of multiple process units within a large industrial plant will usually contain less detail and may be called block flow diagrams or schematic flow diagrams.

5.2.2 Introduction for Piping and instrumentation diagram/drawing (P&ID):

P&ID is a diagram in the process industry which shows the piping of the process flow together with the installed equipment and instrumentation.

P&ID’s play a significant role in the maintenance and modification of the process that it describes. It is critical to demonstrate the physical sequence of equipment and systems, as well as how these systems connect. During the design stage, the diagram also provides the basis for the development of system control schemes, allowing for further safety and operational investigations, such as the hazard and operability study (HAZOP).

For processing facilities, it is a pictorial representation of:

1. Key piping and instrument details
2. Control and shutdown schemes
3. Safety and regulatory requirements
4. Basic start up and operational information

Typically, piping and instrumentation diagrams of a single process system will include the following:

1. Instrumentation and designations
2. Mechanical equipment with names and numbers
3. All valves and their identifications
4. Process piping, sizes and identification
5. Sampling lines, reducers, increasers
6. Permanent start-up and flush lines
7. Flow directions
8. Interconnections references
9. Control inputs and outputs, interlocks
10. Computer control system input
11. Identification of mechanical packages

5.2.3 Introduction for System control diagram/drawing (SCD)

The SCD concept returns to the basis of the system function. The SCD shall focus on representing systems and functional relationships, not individual physical equipment. The SCD combines all functional design requirements into a common unambiguous document.

The automation functions are represented by a limited number of high-level function templates. Each template represents a specific control philosophy selected for a class of objects. The control philosophy is defined / limited by a general range of attributes made available for the specific application. The application level is defined by using the applicable attributes. Complex control and interlocking strategies are developed by inter-connecting templates.

The SCD function templates are vendor independent, thus a set of SCD’s may serve as a functional SAS specification, even before the system vendor is selected.

The SCD’s will be the link between P&ID and implementation of the control functionality in the SAS system.

The SCD documentation is intended to cover the complete life cycle of a process plant:

- Engineering
- Implementation
- Commissioning
- Operations
- Modifications

NORSOK I-005 is a standard developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness to petroleum industry developments and operations. It is intended to cover functional as well as drawing related requirements for use of System Control Diagrams.

The SCDs are developed by the automation engineers in close cooperation with other disciplines. The main premise providers for developing the SCD are the process department and changes in their documents will affect the SCDs. It is therefore important that the P&IDs are issued before the SCDs, and that it is enough time for the system group to finalize the SCDs after the P&IDs have been issued before the release date. Since the developments of the SCDs are dependent on a multidiscipline input at a mature level the SCDs are normally developed during detailed engineering [15].

5.3 International standards and client technical requirements

The ISO 11064 is one of the standards used for design of CR in the case study. Please refer to part 3.1 for details regarding the relevant cases from the ISO 11064 for this case study.
Technical requirements 1212 (client document for the case study, TR 1212) provides requirements for the human machine interfaces on operator stations for safety and automation systems (SAS). The general principles and the philosophy to be applied when designing and evaluating the HMI in the SAS projects are described in the TR 1212.
Further, the design rationale is provided and detailed requirements for the graphical formats and elements to be used had been presented in the TR. SAS performs monitoring, logic control; safeguarding and information presentation in a plant also has been described in detail.
In addition a Guide Line for the TR has been used in the case study, GL 1212. The additional information about the design process and also more detail about different part of the TR 1212 have been described in the GL.
Both the TR 1212 and GL 1212 did not include any detail information about the Large Screen Design process [18].

5.4 General information about the Safety and automation system/Software supplier

The SAS supplier for this case study has been ABB, Oslo. The OGP REUSE Solutions software has been chosen by the client in the project.

REUSE Solutions delivered by ABB are based on requirements from NORSOK I-005, NORSOK I-002 SAS, and alarm philosophy from Norwegian Petroleum Safety Authority Publication YA-711, and also based on IEC 61508 and API RP 14C.

For this case study the SAS supplier developed the graphic library within OGP REUSE Solutions further in order to comply with TR 1212.

This report has the main focus on the HMI design process and not the details regarding graphic and element presentations. There is not included any more details regarding the software.

But further in this case study it has been discussed the effect of involving a programmer representative early in the HMI design process.

6 HMI DESIGN PHILOSOPHY FOR THE CASE STUDY

6.1 Introduction

The case study involves the development and construction of part of a new plant. The purpose of the plant is to receive flue gas from 2 different sources and deliver the flue gas with specified temperature and pressure to 3 interface plants.

A simple diagram is shown in figure 8 to illustrate different process scenarios for delivering of the flue gas which is going to be described in details further in this report.

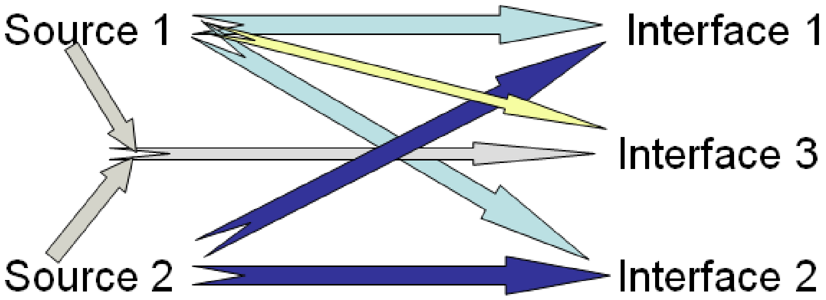


Figure 8: Different process scenarios in case study

Source 1 can deliver flue gas to interface 1 or interface 2, but not both at the same time. Also source one can deliver flue gas to interface 3 at the same time of delivering gas to one of the other interfaces. The last process scenario from the source one is to deliver gas only to interface3.

Source 2 can deliver flue gas to interface 1 or interface 2, but not both at the same time. Also source 2 can deliver flue gas to interface 3 at the same time of delivering gas to one of the other interface plants.

The flue gas from sources shall not be delivered to the interface plant 1 and 2 at the same time.

There are interface signals between the following plants and the Flue gas system:

- Flue gas system(ESD,PSD,PCS) ↔ Source 1(ESD,PSD,PCS)
- Flue gas system(PSD,PCS) ↔ Source 2(PSD,PCS)
- Flue gas system (PSD,PCS)↔ Interface 1(PSD,PCS)
- Flue gas system(PSD,PCS) ↔ Interface 2(PSD,PCS)
- Flue gas system (PSD,PCS)↔ Interface 3(PSD,PCS)

.

The control room consists of 3 control rooms divided in 3 parts. As shown in figure 9, in the left side is the CR for interface plant 1 and 3 and in the right side is the CR for interface plant 2 and the main plant CR in the middle which is the topic of this report. The safety systems shall be operated by the main plant's operator and in emergency situations the main plant operator will be in charge.

It shall be possible to perform all control and monitoring of the different plants from the corresponding operator stations in the CR-s. The dedicated plant operator stations shall only control their own plant, but in emergency situations the main plant operator shall be able to take control the safety of the entire facility.

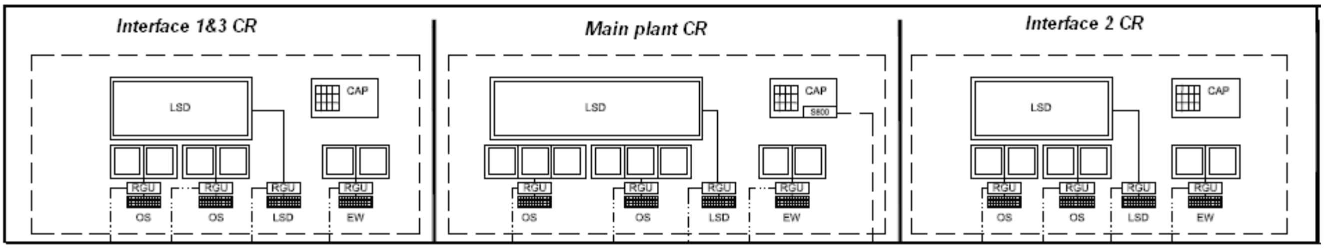


Figure 9: CR Overview (part of SAS topology)

6.2 Purpose of the HMI design philosophy

The objective of this philosophy is to describe the framework and to define the key design principles for the HMI design process. The TR 1212(client document) describes in details the structure of the human-machine interfaces and this document describes the HMI design process and defines the documents which are going to be delivered to the SAS supplier and the key information. Details regarding following parts, Requirements for presentation and interaction in the main area (TR1212-5) and detailed HMI requirements (TR1212-6) are included in the client document TR 1212 which is used for the HMI design and this philosophy just specifies the design process philosophy and development process in detail.

The main goal for the HMI design is that the HMI design shall fill out the following factors for the end-users:

1. Easy to learn, use and remember
2. Error tolerant
3. Efficient
4. Motivating and comfortable to use

In order to achieve these goals the whole process of HMI design is based on the ISO 11064 and TR 1212, which includes that the design process shall be done with a multidiscipline design team and involving the end-users early in the design process.

6.3 Normative and informative references

TR1212, SAS operator station HMI, Ver.1[18]

ISO 11064, Ergonomic Design of Control Centers

NORSOK I-005, System Control Diagram [10]

ALARM PHILOSOPHY, SAS TOPOLOGY, HUMAN FACTORS STUDY - TASK ANALYSIS

6.4 HMI development process

To achieve the best possible design of the human machine interface, the human operator shall at all time be the highest authority in the human machine system. Requirements of human factors in HMI design is described in the client documents for the case study.

Based on the project standards and client TR's the design shall be based on a multidisciplinary design team, involving end-users. End-users involvement is considered to be a very effective tool for the design process. This method for HMI design can improve the operator performance in CR.

The basic for HMI design are operator tasks and control logic. The main multidisciplinary HMI design team in the project consists of operators, automation engineers, process engineers, human factors specialist and programming engineers/representative, with help of other engineering groups when it is needed (Such as safety for F&G system, telecom for telecom pictures, electro regarding electro pages and HVAC for HVAC system).

In order to design an efficient and user friendly interface, there are specific requirements for the design process which is described in this part of the HMI design philosophy.

The main control room is equipped with LSD and two operator work stations. Neither the TR (client document) nor ISO 11064 has any recommendation about the LSD design. But in the project it is decided to use the same HMI development process for the LSD as for the operator work stations.

The first step is to establish a multidisciplinary team and make a plan for the design process with milestones (included V&V activities), including when different persons in the team shall be involved. In order to keep track of the design process; with recommendations and decisions taken during the design a log system shall be used [18].

The following steps describe the HMI design process based on Ref. [18], 2009:

1. *Multidisciplinary design group (HMI responsible/Automation engineer, HF specialist, Programming engineer/SAS Supplier, End-user) defines the goal of HMI for LSD and each system/Level based on the operator task/task analysis.*

2. *Use the experience from similar systems (in form of report, other project, and experiences).*

3. *Systematic function and task analyses are performed for each system based on Relevant standards and TR's (Or if the plant technology is well understood and the multidisciplinary design group contains of experienced operators, the "Talk Through" can be used instead.)*

4. *Workshops to develop prototypes/sketches of the HMI pictures are arranged with participation of multidisciplinary design team. The Sketches are made by the HMI responsible/Automation engineer (SCD designer).*

5. *First V&V, evaluating the sketches/prototypes by multidisciplinary design group. (HMI Responsible/automation engineer, HF, end-user, safety/process/electro engineer and Programming engineer)*
   The multidisciplinary design group shall agree on the prototypes/drawings, and then Drawings shall be delivered to SAS supplier as a base document for configuration of HMI.

6. *Evaluating pages by V&V activities during programming, first when the basic of pictures are ready to evaluate and second time after the programming is finished with a multidisciplinary design group (HMI responsible/Automation engineer, HF, End-user).*

8. *When a change is required the relevant steps shall be repeated.*

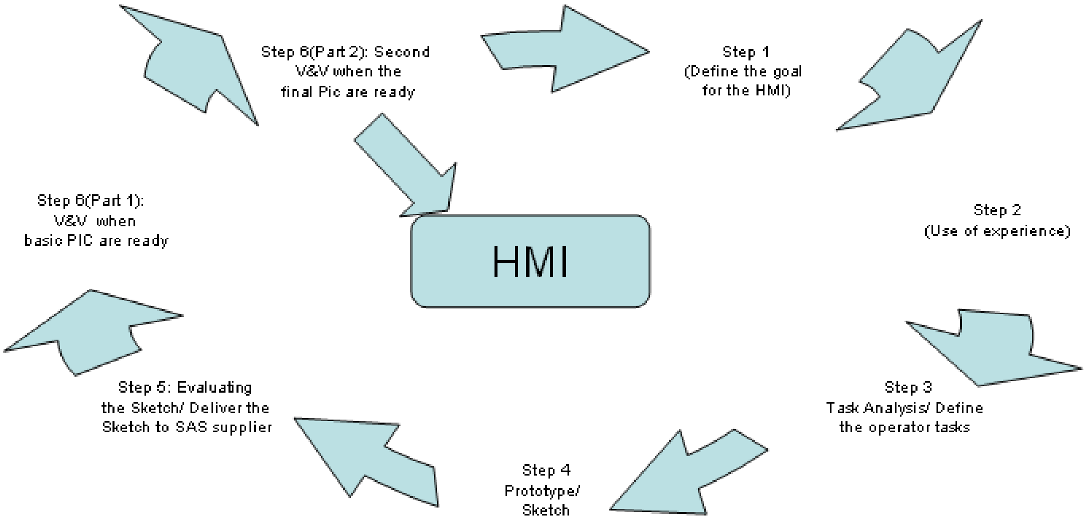


Figure 10: HMI Design Process

6.5 Page hierarchy Philosophy

The main part of CR consists of two operator stations and one LSD. Each operator stations consist of three screens, one keyboard and one mouse.

The page hierarchy for HMI consists of four levels. Each level is described in this part.

6.5.1 Large screen display (Level 1)

The overview page on LSD is shown permanently and no process control or system interaction is available in this level.

The LSD design can affect the other lower levels in the HMI design process. The HMI group shall discuss this topic and goals for LSD first before start of discussing other levels for the plant's HMI design (Refer to chapter 10 for more information regarding LSD design).

6.5.2 Screen layout (Level 2- 4)

Part 4.1.3 in TR 1212 [18] shall be used for screen layout for level 2, 3 and 4 which includes information regarding screen layout with its various areas.

6.5.2.1 Level 2 Overview

Level 2 consist of Overview pages, ESD hierarchy, PSD hierarchy, Process overview, F&G, Electro display, Telecom. Number of pages shall be defined through the multidisciplinary HMI design process meetings.
The team should consider the effect of including of overview pages with possibility for start /stop of main equipment or systems. A good overview process page in this level can affect the pages on level 3 and level 4.

6.5.2.2 Level 3 Detail process pages

Level 3 consist of detail Process displays (included PSD levels). Number of pages shall be defined through the multidisciplinary HMI process design meetings.

6.5.2.3 Level 4 Mechanical process pages

Level 4 consist of detail equipment/mechanical Packages control displays (Pumps, Blowers, Compressors).

Number of pages shall be defined through the multidisciplinary HMI process design meetings.

6.6 HMI Style guide line

The HMI style guide line was specified in the client technical requirements document TR 1212 and was used for the case study. This report does not include any more detail information in that matter.

6.7 Operator training

It is required that proper training of relevant personnel will be taken care of by training courses in use of the SAS system according to the operation company requirements.

Such training should cater for:

- The purpose of the whole systems
- Training for all different scenarios(PCS,PSD & ESD)
- Context handling
- Alarm suppress and alarm hiding techniques
- User interface – presentation and audible sounds
- Use of the alarm system in different context modes

6.8 Example for the design process

An overview of design process for LSD (includes step 1 to 5) described in part 6.4:

Define the main goals of LSD in CR, define different Zones, and define size of each Zone and define which operation scenario shall be supported by LSD. Then make a sketch, V&V and deliver the final sketch to the programmer.

An overview for design process of pages for each system in Level 2, 3, 4 (includes step 1 to 5) described in part 6.4:
Define main Goal for the page (consider the effects on level 3 and 4 pages), make the first Sketch, V&V and deliver the final sketch to the programmer/SAS Supplier.
The Sketch which is going to be delivered to the SAS supplier includes the main elements of each interface page with a attached mark-up including tag number, the number of the page and page title. The logic is not included in these sketches and the SAS supplier shall use these sketches for HMI programming with the logic shown on the system control diagrams.

7 FLUE GAS SYSTEM

In this chapter the process system called Flue gas system is described in details to give an overview of the technical part of the design and also represent the technical documents which is used during the HMI design process. This part represent a short presentation of this system and overview of relevant engineering documents.

The chapters 7.3, 7.4, 7.5, 7.6 and 7.7 are part of the document called “IPF and control narratives” which is developed by the automation engineers. These chapters is included to describe a short summary about the control function philosophy design for the flue gas system source 1.These can show why the automation engineer/SCD designer shall be part of the HMI design group. The work needed for specifying the operator task regarding each system is much easier when there is a member in the HMI design group who has complete overview of the control system functionality and the philosophy behind the sequences. Please notice that for understanding the chapters 7.3, 7.4, 7.5, 7.6 and 7.7 some basic knowledge about NORSOK I-005 [10] is required.

7.1 System Scope

Refer to the following P&ID’s and SCD‘s:

• P&ID-01	Flue Gas Blower 1
• P&ID-02	Direct Contact Cooler 1
• P&ID-03	Flue Gas Blower Package 1
• P&ID-04	Oil System Blower Package 1
• SCD-01-01	Flue Gas Blower 1
• SCD-01-02	Direct Contact Cooler 1
• SCD-01-03	Feed Gas To Interface 1,2 and 3
• SCD-01-04	Flue Gas To Interface 3 from Flue gas source 1or 2

7.2 System Description

The Flue Gas System comprises of the following main equipment:

- Flue Gas Separator
- Flue Gas Blower 1
- Direct Contact Cooler 1
- DCC Water Pump 1
- DCC Water Cooler 1
- Lube Oil Pump A
- Lube Oil Pump B

The purpose of the system is to treat the flue gas from the Source 1 to meet the required specifications for the interface 1, 2 or 3.

The flue gas from the source 1 is available from outlet of the existing seawater scrubber. The flue gas contains catalytic particles carried over from the source 1 and entrained seawater from the scrubber. A flue gas separator located close to the tie-in point will clean the gas to the extent possible. Thereafter the flue gas is pressurized by the flue gas blower 1 in order to meet the required pressure for the interface plants.

Direct Contact Cooler (DCC) 1 is employed to cool the gas to the desired temperature and to remove contamination that has escaped the flue gas separator. In the DCC 1, hot flue gas is cooled by a counter current circulating water stream. The water stream leaves at the bottom of the DCC 1 and rejects heat in a seawater plate heat exchanger, DCC Water Cooler. DCC water pump 1 circulates the water from the bottom of the DCC through the heat exchanger and into the top of the DCC.

The temperature of the recirculation water is controlled by bypassing the DCC Water Cooler. If it is not required cooling the entire water flow will bypass the heat exchanger. If the required higher temperature the low pressure steam is injected downstream the DCC 1 to raise the flue gas temperature to the desired value.

Based on the requirements given, the interface plants shall be able to operate on either of the two flue gas sources (1 or 2) at any given time.
For the scenario of flue gas source 1 supplying the interface plant 3 please see chapter 8 in this document.

The fallowing diagram (figure 11) is the PFD for Flue gas system Source 1.

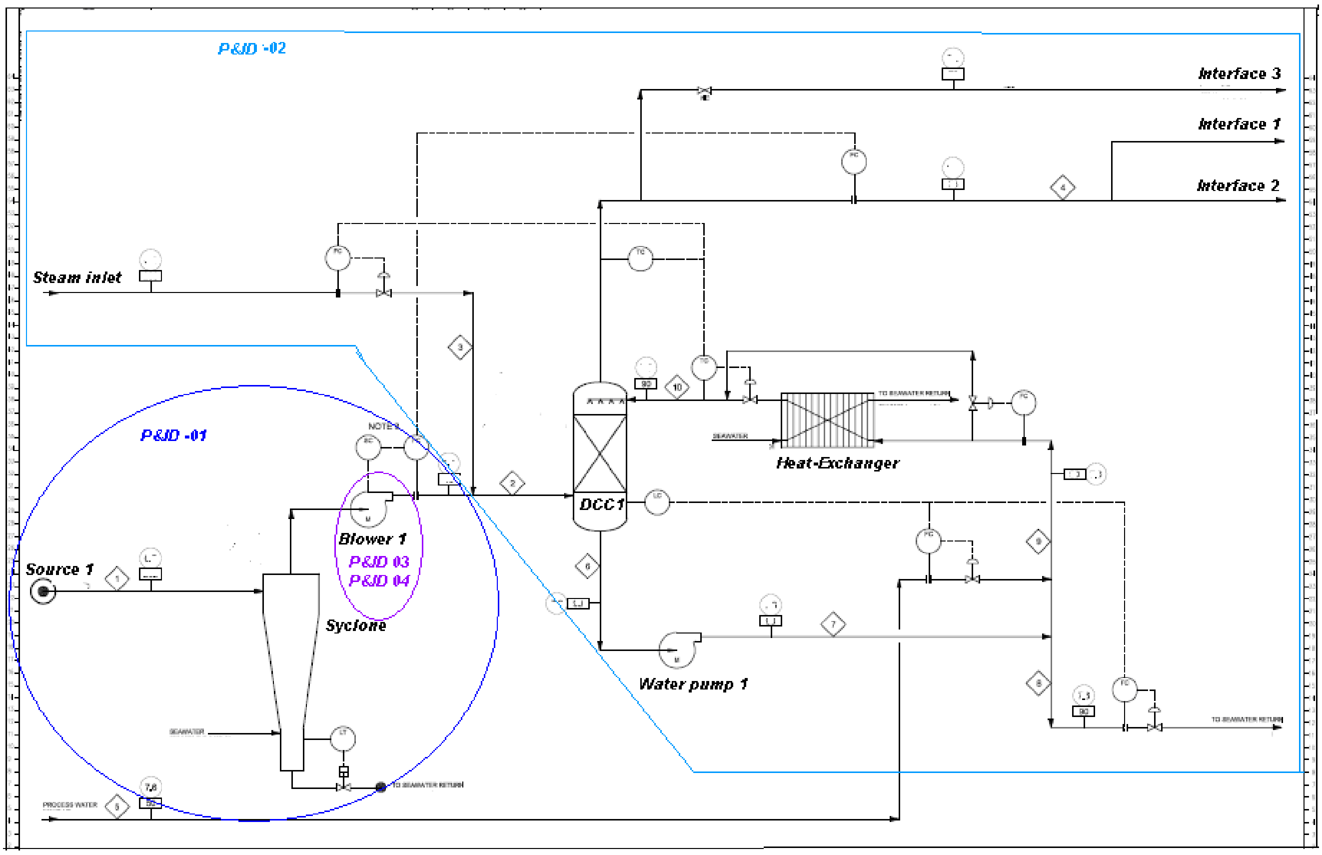


Figure 11: PFD-Flue gas source1

This PFD shown in figure 11 is a simple version of the real PFD for this system. All information from the original PFD which is not relevant for the HMI design process is deleted. As shown in the figure 11, this system has 4 P&ID's, the deviation of different P&ID's is shown with different colors in figure 11 to give a better understanding about how much information this single process engineering document includes.

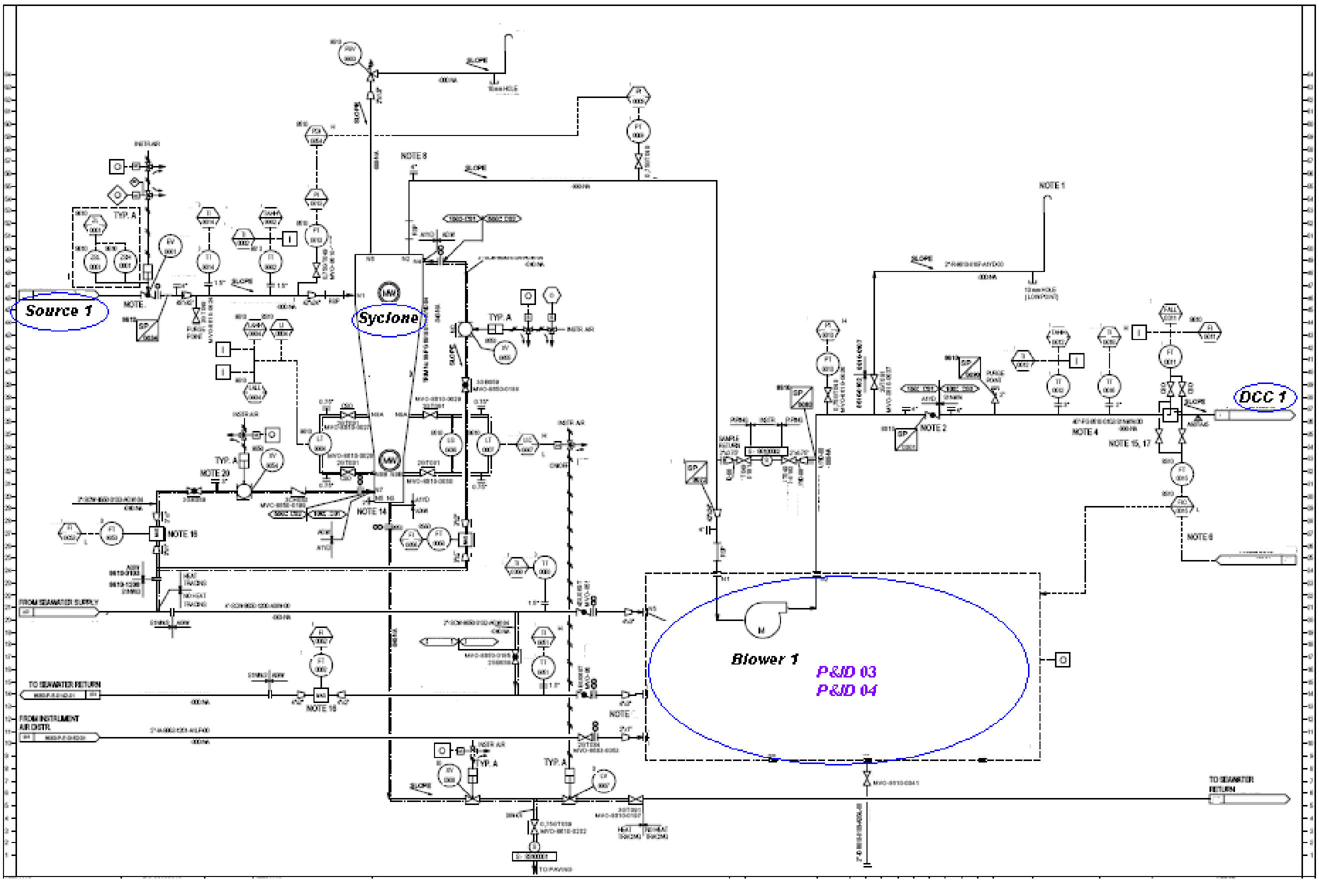


Figure 12: P&ID-01, Flue Gas Blower 1

Figure 12 is the P&ID for flue gas blower 1. Flue gas from source 1 is send to the blower through the cyclone after that send to direct contact cooler 1 which is shown in the next P&ID.

In P&ID-01(figure 12), the flue gas inlet point, the flue gas cyclone, blower 1 and the outlet flue gas line to the next P&ID is highlighted with blue color.

And also it is shown that the Blower package includes two P&ID‘s.

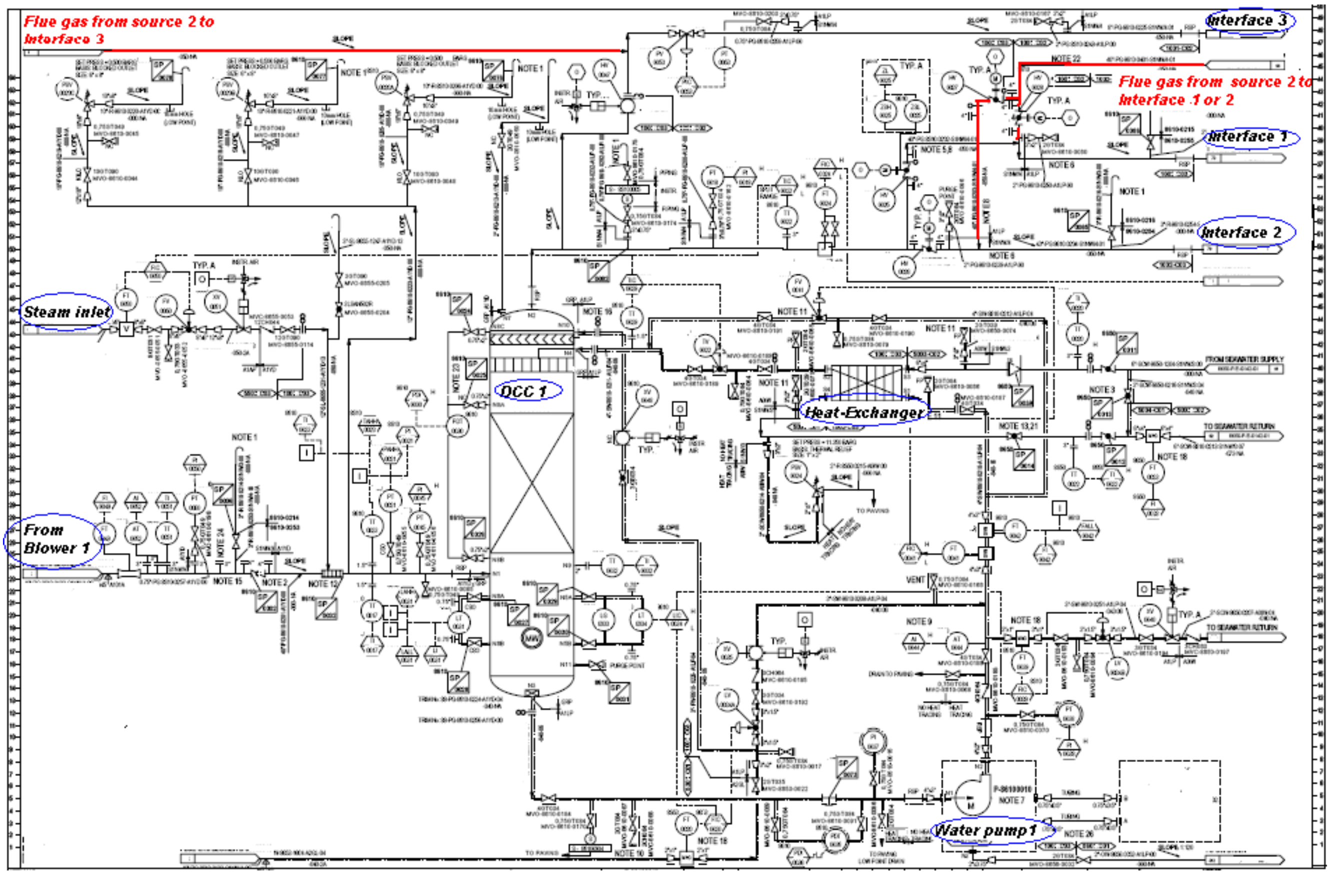


Figure 13: P&ID-02, direct contact cooler 1

The rest of the system is shown in the P&ID-02, figure 13.

The red mark up lines is the process line from source 2 which is almost a similar system from another flue gas source.

The flue gas system from source 2 is not included in this part of the case study, but an overview of this part is included in LSD part of the case study.

As shown in the PFD (figure 11) and P&ID-01 (figure 12) the blower package includes two P&ID. Bower package includes the instrumentations around the blower. It means that the instrumentations in P&ID-03 & 04 shown in figure 14 and 15 just are directly related to the blower performance.

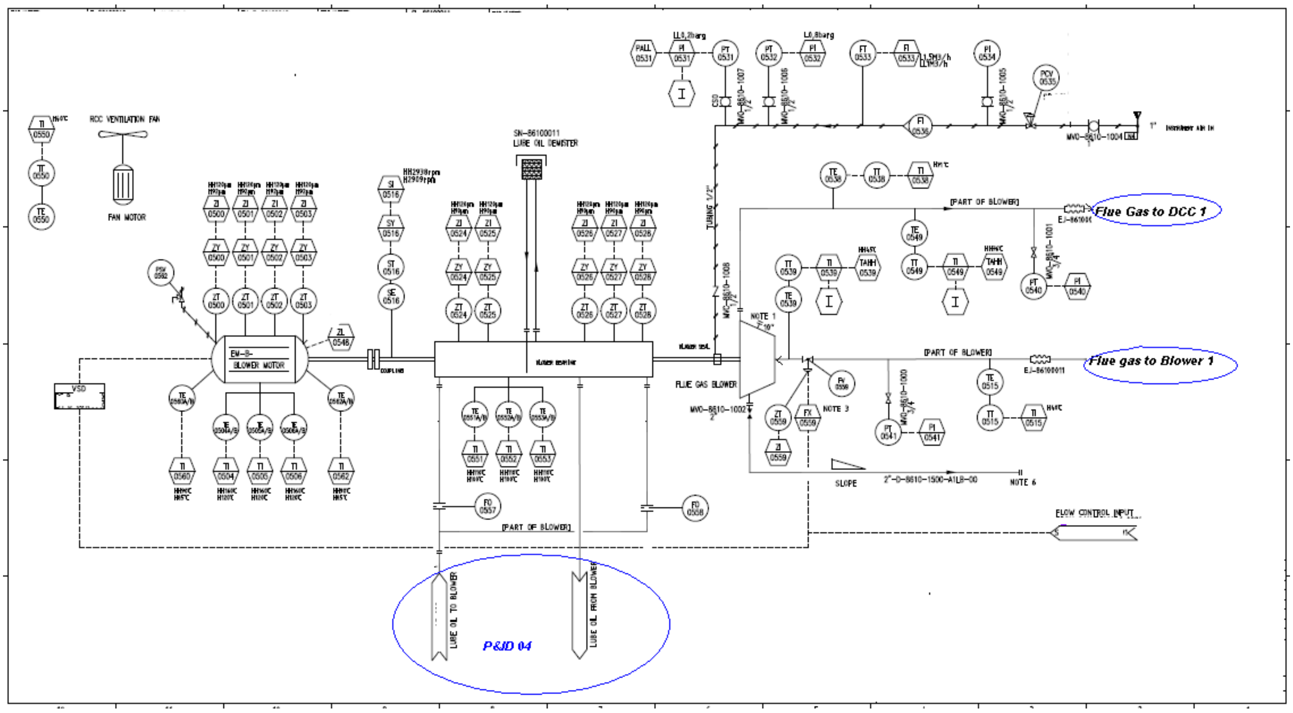


Figure 14: P&ID 03, Flue Gas Blower Package 1

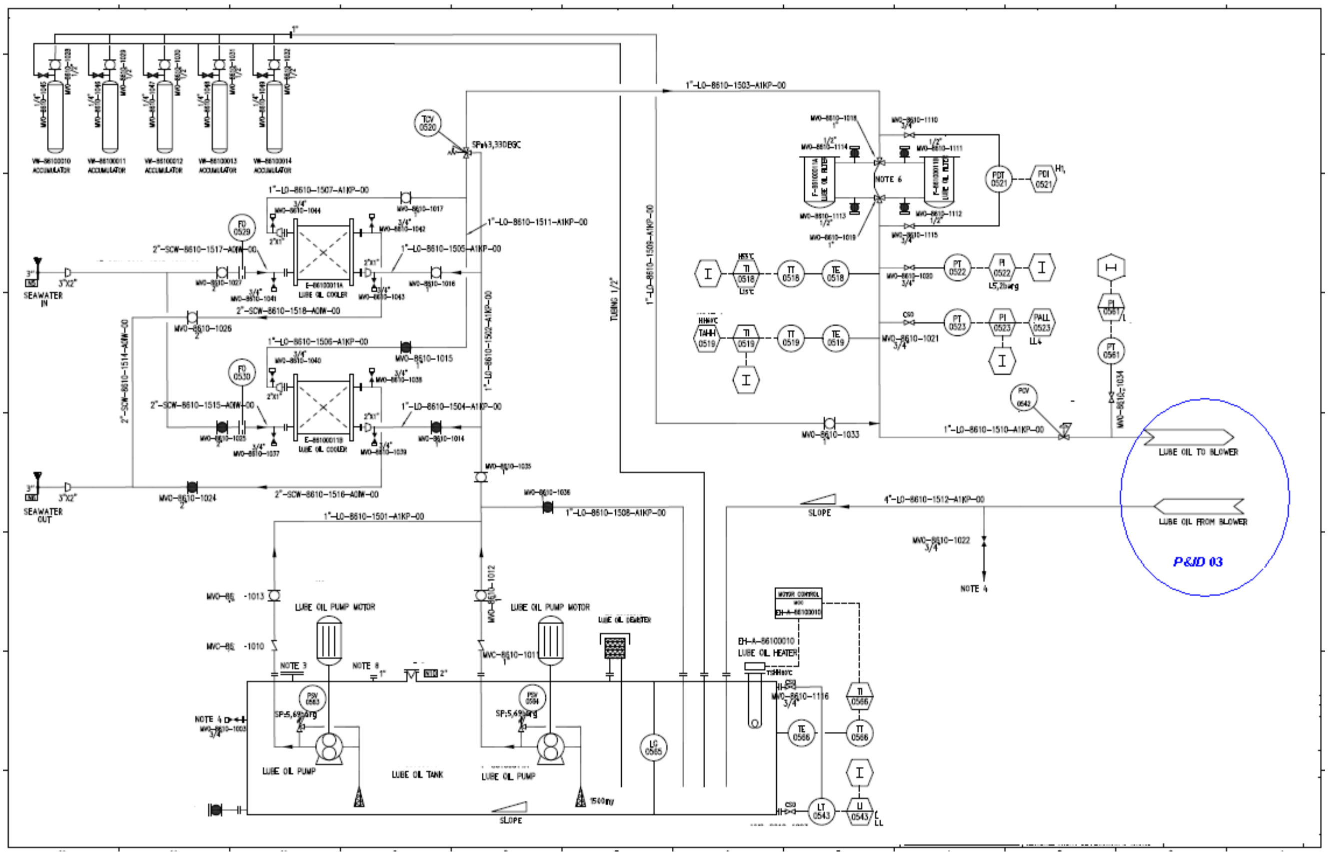


Figure 15: P&ID 04, Oil system Blower Package 1

7.3 System Control Description Normal Operation

The flue gas from source 1 contains catalytic particles following from the unit and entrained seawater from the scrubber. A flue gas separator will clean the gas to the extent possible. Level in the Flue Gas Separator is controlled by Level controller LIC-0007 by sending BXL or BXH signal to LV-0007(SBV function block) to control close the valve on BXL and opening the valve on BXH.

Thereafter the flue gas is pressurized by the flue gas blower 1 in order to meet the required pressure for the interface plants. The Blower has VSD control, Flue Gas flow rate send by the interface plants through cascade regulation between the controller FIC-0024 and the controller FIC-0015 sends the final set point to the Blower and the IGV (inlet guide valve) in a split range control. I.e. depending on the flow rate demand the IGV shall be in 100% open position before the blower speed takes over.

Direct Contact Cooler (DCC) 1 is employed to cool the gas to the desired temperature and to remove contaminations that have escaped the flue gas separator. In the DCC, hot flue gas is cooled by a counter current circulating water stream. The level controller LIC-0034 on the Direct Contact Cooler 1controls level in the DCC by split range between FIC-0020 which sets the valve opening for LV-0034A and FIC-0039 sets the valve opening for LV-0034B. Valve A is located at the process water make-up inlet. Valve B lets excessive cooling water to effluent water treatment plant.

The water stream leaves at the bottom of the DCC and rejects heat in a seawater plate heat exchanger, DCC Water Cooler 1. DCC Water Pump circulates the water from the bottom of the DCC through the heat exchanger and into the top of the DCC. The only consumers connected to the flue gas condition system are the interface plants. The Flow of the water to the top of the DCC Direct Contact Cooler is controlled by Flow Controller FIC-0041, through sending signal to open flow control valve FV-0041.

The temperature controller TIC-0022 controls the temperature of the flue gas by split range control through TIC-0029 adjusting the water temperature and FIC-0050 for use of steam. The water temperature is controlled by adjusting the amount of water bypassing heat exchanger.TIC-0022 also controls Low pressure Steam inlet by sending external set point value to Flow Controller FIC-0050. The Flow Controller FIC-0050 gets input signal from the flow transmitter FT-0050. Steam is injected to control the flue gas temperature.

7.4 Functional Requirements

The Interface plant 1 and interface plant 2 shall be independent of each other operational wise in such a way that one of the plants can be taken out of operation for maintenance and inspection while the other plant is not affected.

The Flue Gas System supplies Flue Gas at required temperature and pressure to one of the two interface plants.
Two separate inlet flue gas lines are provided, one cooled flue gas to the Interface 1 and one to the Interface 2. The two lines are interconnected via Hand Valves crossovers. This inter-connection allows gas from either source (1or 2) to be routed to either Interface plants. Mixing is not possible.

The following Interlock logic for outlet hand valves to Interface plants is implemented in SCD 01-03.

  - The Hand Valve HV-0028 LSH signal means that source 2 supplies Interface 1, it is required that HV-0027, HV-0025 and HV-0142 are closed.
  - The Hand Valve HV-0027 LSH signal means that source 2 supplies interface2onia, it is required that HV-0026, HV-0028 and HV-0140 are closed.
  - The Hand Valve HV-0025 LSH signal means that source 1 supplies interface 1, it is required that HV-0026, HV-0028 and HV-0140 are closed.
  - The Hand Valve HV-0026 LSH signal means that source 1supplies interface 2, it is required that HV-0027, HV-0025 and HV-0142 are closed.

For More detail please refer to SCD 01-03, figure 18.

7.5 System Start-up and Normal stop

There are two Sequence diagrams regarding Start Up:

- Start Sequence water cooling system
- Start Sequence Flue Gas System- Source 1

Before starting up the Flue Gas system, start permissive implemented in SAS based on information from Engineering Flow Diagrams, System manual and System Control Diagrams has to be met, as well as start permissive from Source 1 CCR for relevant systems and at least one of the Interface plants.
Following systems have interface with the Flue gas system and shall be checked before starting the Flue Gas Blower:

- Source 1
- Instrument air
- Process water
- Sea water
- Steam
- Open drain
- Sea water return
- One of the Interface plants

The operator must ensure that the DCC Water Cooler part of the system is put into operation. The start sequence XU-0001shall start first. After the end of the sequence XU-0001 the start sequence for Flue System XU-0003 can be started. This means that the circulation pump is started and that the circulation flow is stable at the desired set point before starting the Flue Gas Blower.

In addition, the PSD levels for the flue gas system shall be reset. The utility operator also has to choose which one of the interface plant units to receive flue gas from the Source 1 to start-up by choosing HS-0401 or HS-0404.

There are two Sequence diagrams regarding Stop:

- Stop Sequence water cooling system
- Stop Sequence Flue Gas System-Source 1

A planned shutdown/normal stop is done mainly for maintenance or for the Interface plants will change the program. The length and purpose of the shutdown will determine how extensive the shutdown should be. The shutdown is done by gradually running down the speed of the current blower to a minimum speed where the blower stops. When the blower has stopped and the speed goes below BXL the inlet valve EV-0001 (emergency valve) closes by stop sequence. Moreover, should any of the valves to Interface 3 that are open, close automatically when the blower is not running. All conditions mentioned above are included in the stop sequence XU-0004.

If it is not scheduled any maintenance it is recommended that water circulation in the current cooling circuit is maintained as normal, but that it stops any replacement of water in the circuit with the new process water. For longer stops should stop by the circulation pump is considered to conserve energy. It is an operator choice to stop the water cooling part of the system XU-0002.

The sequence diagram is not included in the report, the meaning of this chapter was to give a summary of the complexity of the start and stop of the system, and later in the report it is discussed in detail about how the complexity of start and stop sequences affected the HMI design process.

There are seven PSD levels for this system. The main PSD level for this system is affected by the Source 1 PSD signals and the relevant interface plants which are supplied by Source 1 at the time of activating of the PSD signal.

And all the main PSD level for this system is affected by ESD system if the relevant ESD signal is activated.

7.6 SCD‘s for Flue Gas system-Source 1

As mentioned, this part of Flue Gas system includes 4 SCD diagram. 3 of this SCD‘s includes control logic from source 1 to the interface 1 and 2 and the blower package.

The detail understanding of the SCD’s is not the aim of this report, but the total understanding of the SCD’s is very important to understand the HMI design process.

To simplify the understanding of SCD’s a lot of detail information has been deleted from the attached SCD’s, figure 16, 17, 18 and 19.

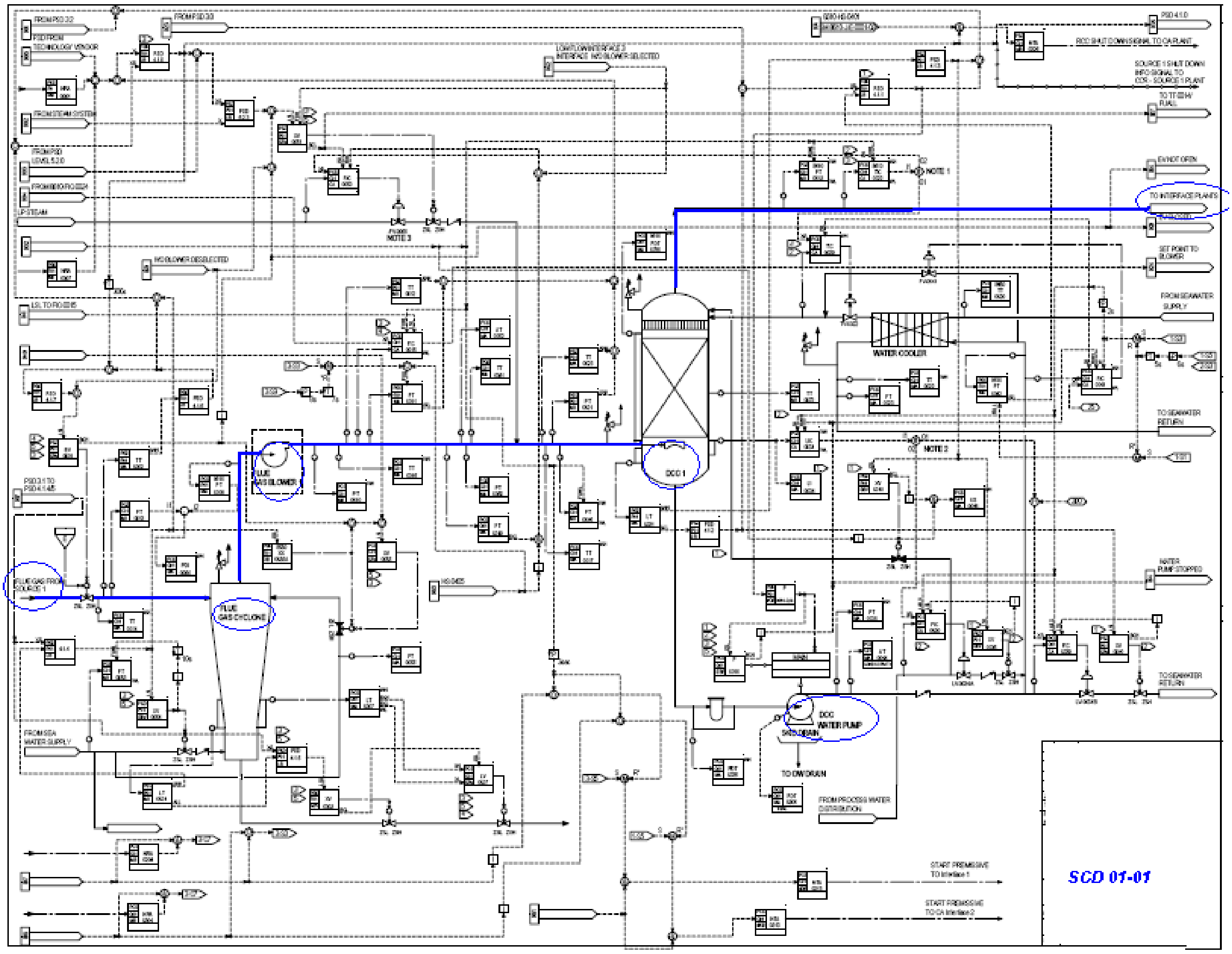


Figure 16: SCD 01-01

SCD 01-01 in figure 16 includes main flue gas line from Source 1 to the interface plants. The main flue gas line is marked with blue. Main equipments which are highlighted by blue circle are the flue gas cyclone; flue gas blower 1, DCC 1, and water pump 1.

This SCD shown above reflects the P&ID 01 and part of the P&ID 02.

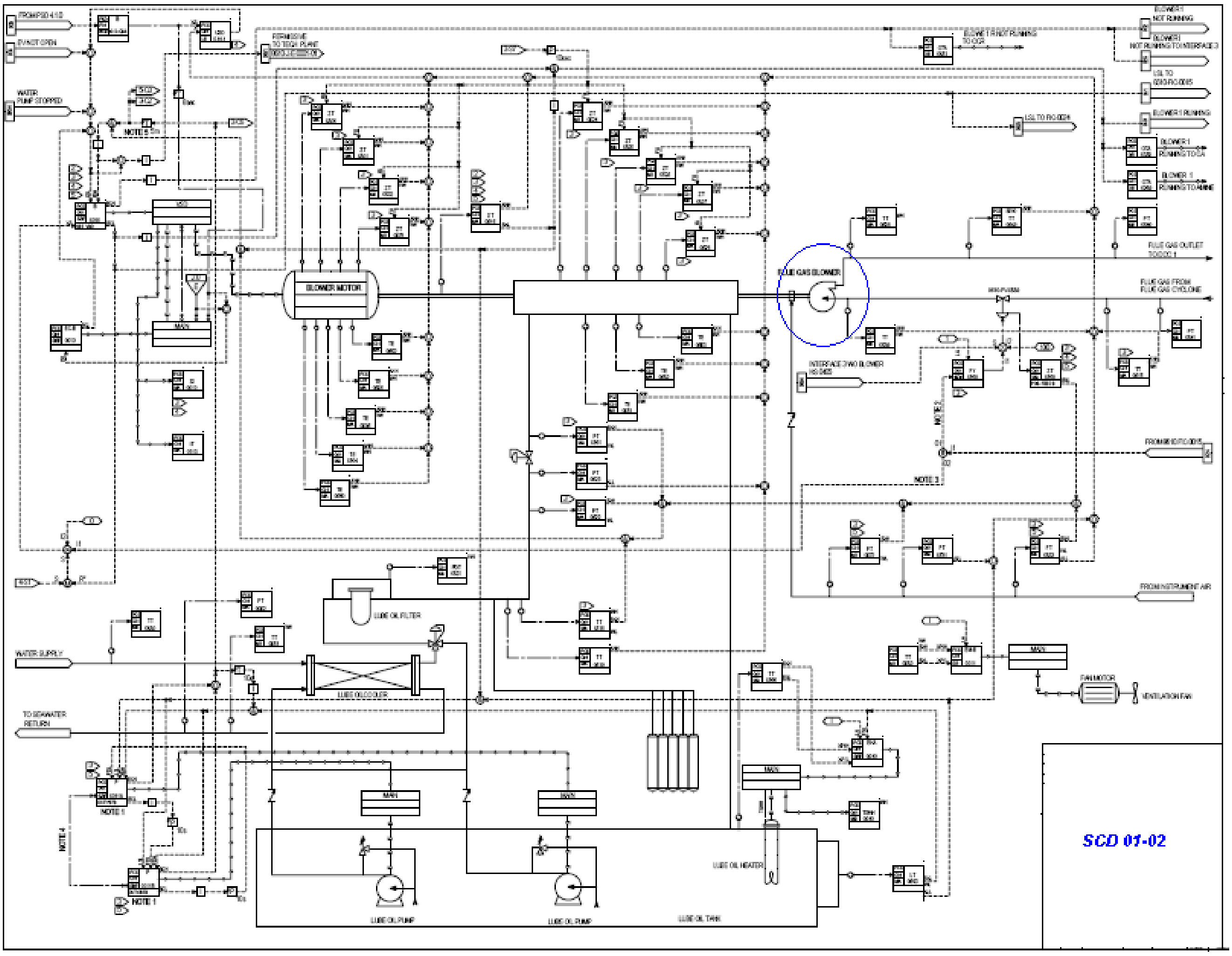


Figure 17: SCD 01-02

SCD 01-02 shown in figure 17 includes main flue gas line from flue gas cyclone to limits of flue gas delivery to the DCC 1 inlet. Main equipment which is highlighted by blue circle is Blower 1.

All the other equipments which are shown in this SCD belong to the Blower package, which reflects the P&ID 03 and P&ID 04.

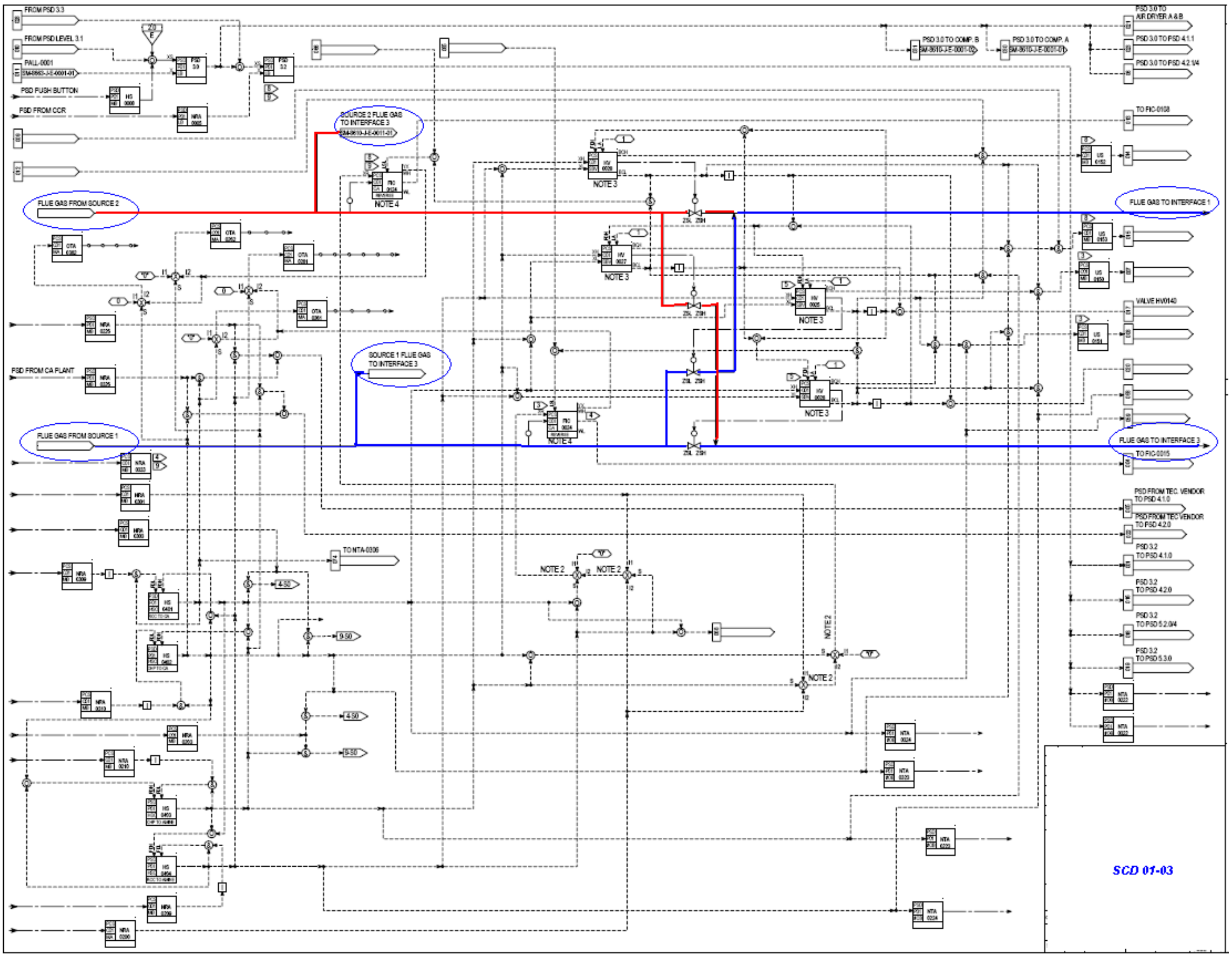


Figure 18: SCD 01-03

The SCD 01-03 in figure 18 shows the flue gas line from Source 1 and 2 to the Interface plants 1 and 2.

The Blue lines are the flue gas line from Source 1 and the red Lines are from the flue gas line from Source 2. The SCD presented in figure 18 presents a complicated interlock logic for four HV valves, two flow regulators and four software hand switch function blocks. In chapter 9, reference number 1, and 20 in figure 27 illustrate the information which was needed to include in the sketch based on the operator task for these system regarding 50% of the logic presented above.

7.7 Source 1 or 2 flue gas to interface 3

7.7.1 System Scope

The Interface 3 can be supplied by Flue gas source 1 or 2, independent from the other interface plants (1 or 2) uses the same source of flue gas.

Interface 3 can also be supplied by source 1 only, for this scenario the blower 1 is not running.

There is designed to Hand Valves, HV-0047 on the line from Source 1 to interface 3 and HV-0146 on the line from Source 2 to interface 3.

In addition there is installed a pressure reducing valve (PV-0053) in flue gas pipeline to interface 3, which takes the pressure to correct set point through PIC-0053.

Selection valves (HV-0047/0146) to interface 3 are interlocked with one another, so it is not possible to access both simultaneously.

SCD 01-04 (figure 19) shows this process scenario and the control logic. The Blue lines are the Flue gas line from Source 1 and the red Lines are from the flue gas line from Source 2.

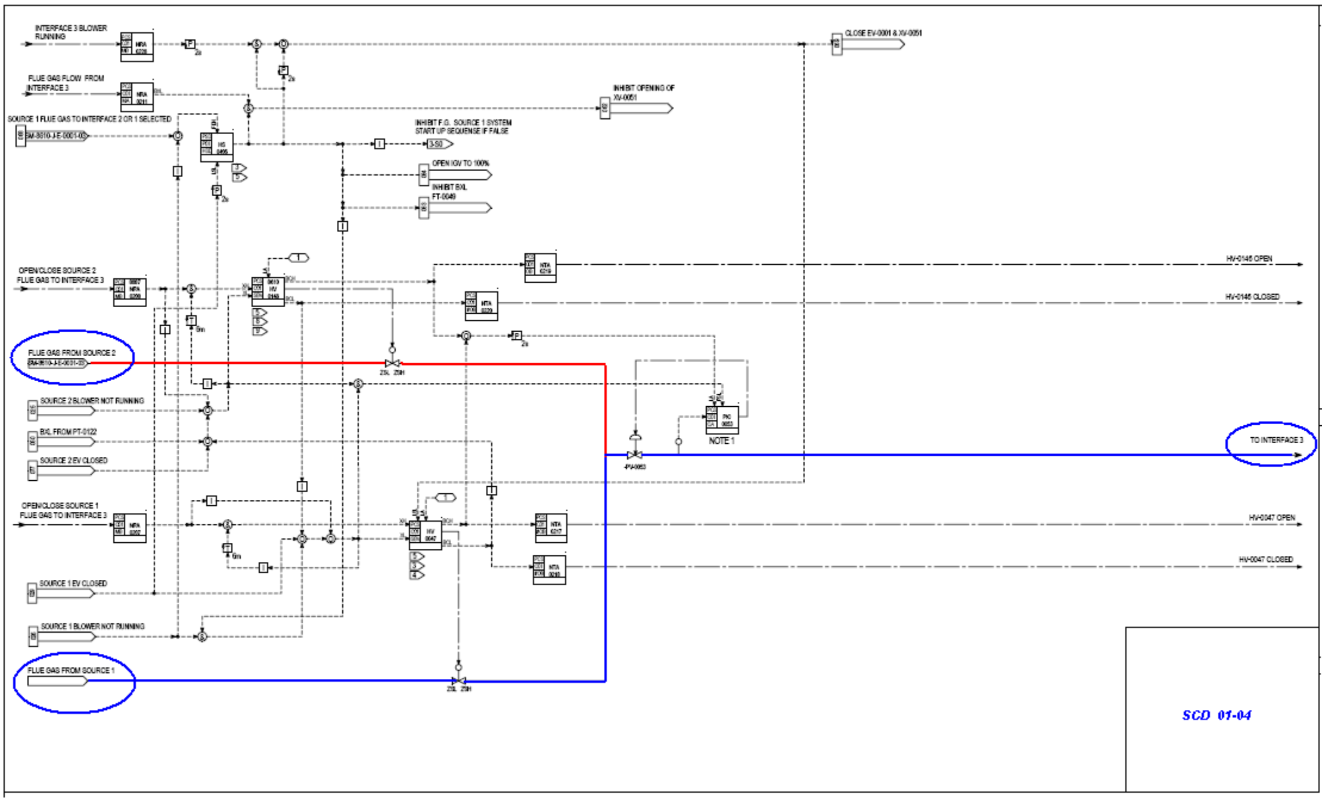


Figure 19: SCD 01-04

There are 3 different scenarios for supply of flue gas to interface 3, the first two scenarios do not have any start or stop sequence, but for the case when interface 3 running alone on flue gas from source 1 there is designed an start sequence.

7.7.2 Flue Gas from source 1 to interface 3 and 2 or 1

When the relevant signal is activated by Interface 3 operator, HV-0047 opens after 6 minutes if all the conditions are met.

The conditions are HV-0146 is closed, Blower running and the inlet EV is open. The time delay of 6 minutes is designed to be sure that the system (pressure and temperature) is stable.

The Interface 3 plant shall use the position feedback signal from the valve to stop their plant.

7.7.3 Interface 3 running on Source 1 flue gas only (Blower not running)

When Interface 3 is operating based on Flue Gas from Source 1, Blower 1 shall not be in operation but the lube oil system in the blower package shall be running and the IGV valve shall be in 100% open position.

The HS-0405 shall be used for the start of this scenario by operator. Then the start sequence XU-0005 shall be activated by operator.

There is not designed a stop sequence for this scenario. By de-selection of the HS-0405 stop actions are done by the control logic.

8 HMI DESIGN PROCESS FOR THE PROCESS SYSTEM

In chapter 6 and 7 all the information relevant for HMI design process and the engineering documents which is used for the design process is presented, this chapter is based on author observation and participation in the case study.

To present a better picture about the difference between the SCD‘s and P&ID’s the PFD below shows how the original PFD is divided to different SCD’s (in red) and P&ID’s, figure 20.

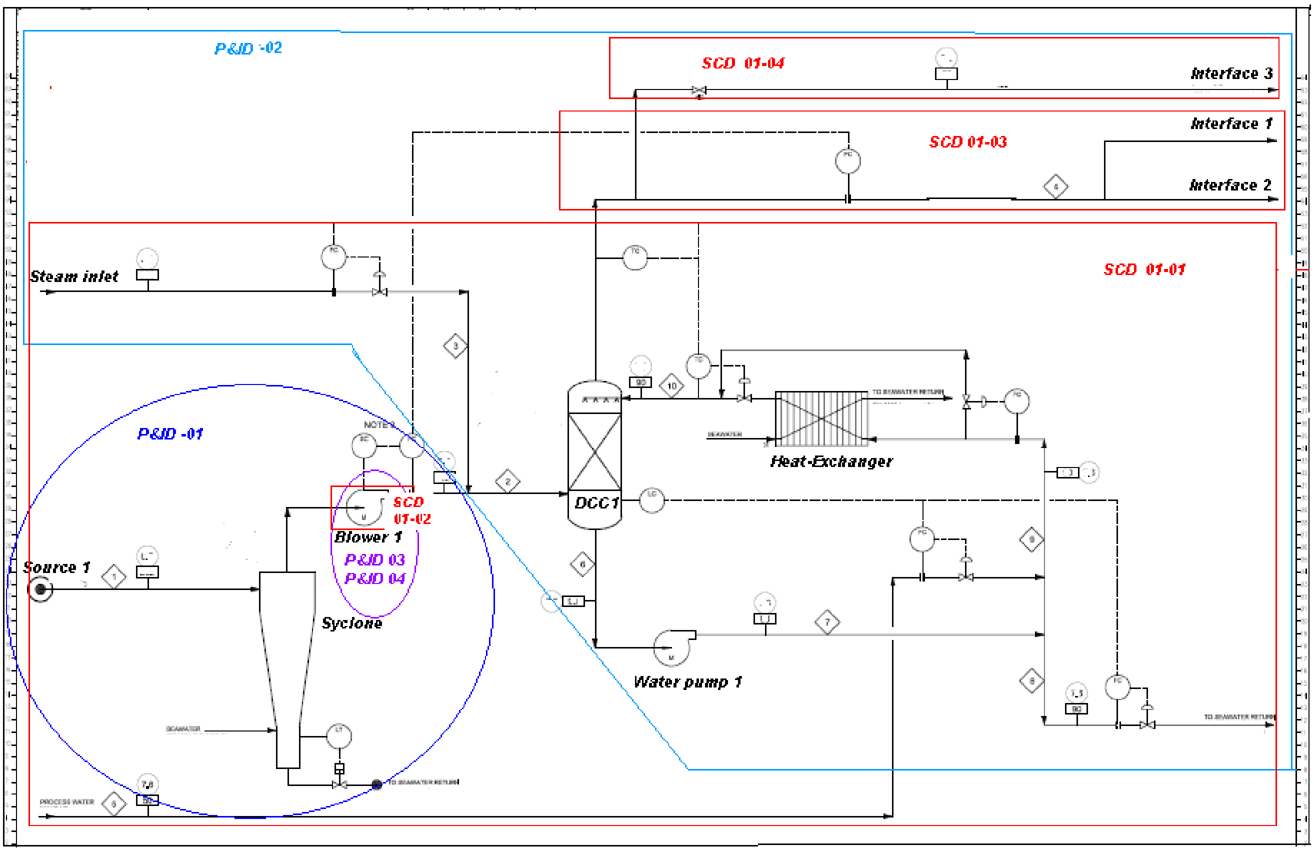


Figure 20: PFD deviation to P&ID’s and SCD’s

There is some misunderstanding that engineers who has not worked with the SCD design thinks that the SCD’s deviation is exactly like the P&ID’s. The PFD shown in the figure 20 shows that SCD and P&ID‘s are two different type of design engineering documents with two different deviations philosophy. Another example is that SCD 01-03 is made for the logic of small part of the P&ID-02 (in blue) in the case study shown in figure 21.

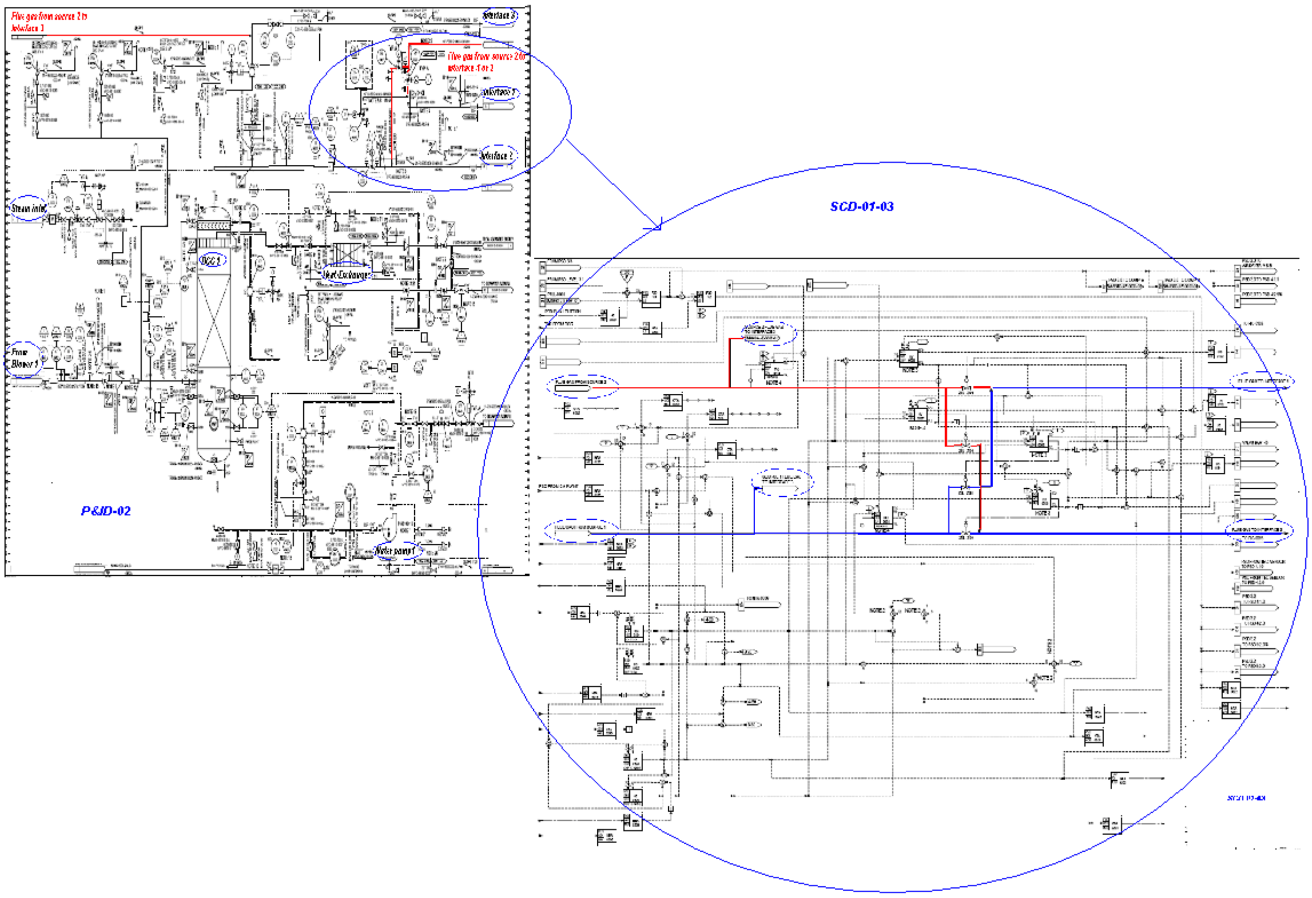


Figure 21: Relation between P&ID and SCD

Further in this part is shown that the SCD's is very helpful for design of a better HMI but the designer shall free their mind from the SCD's to be able to develop a HMI which is more useful for the end-user regarding operator task related to the system.

In the HMI design process for this part of Flue gas system, all the engineering documents relevant for the system has been used.

HMI development process for this case study has been described generally in chapter 6.4. In step four of the development process has been mentioned that Prototypes/sketches shall be made for each process HMI. This project has been one of the few projects where it has been included HMI sketches as an engineering document during detail engineering.

The multidisciplinary design team decided that one typical sketch based on main part of the Flue gas system-Source one shall be made and a typical HMI shall be developed by the SAS supplier. This was the very first step to find out that how this part of the process is going to work.

The first sketch was made by the multidisciplinary design team. Regarding the short time for this activity it wasn't possible to involve the end-user in such a short notice.

The figure 22 is the first sketch. The engineering documents which have been used were the P&ID-01, P&ID-02, SCD-01-01, part of the SCD 01-03 and part of the SCD 01-04 and the PFD for the flue gas system.

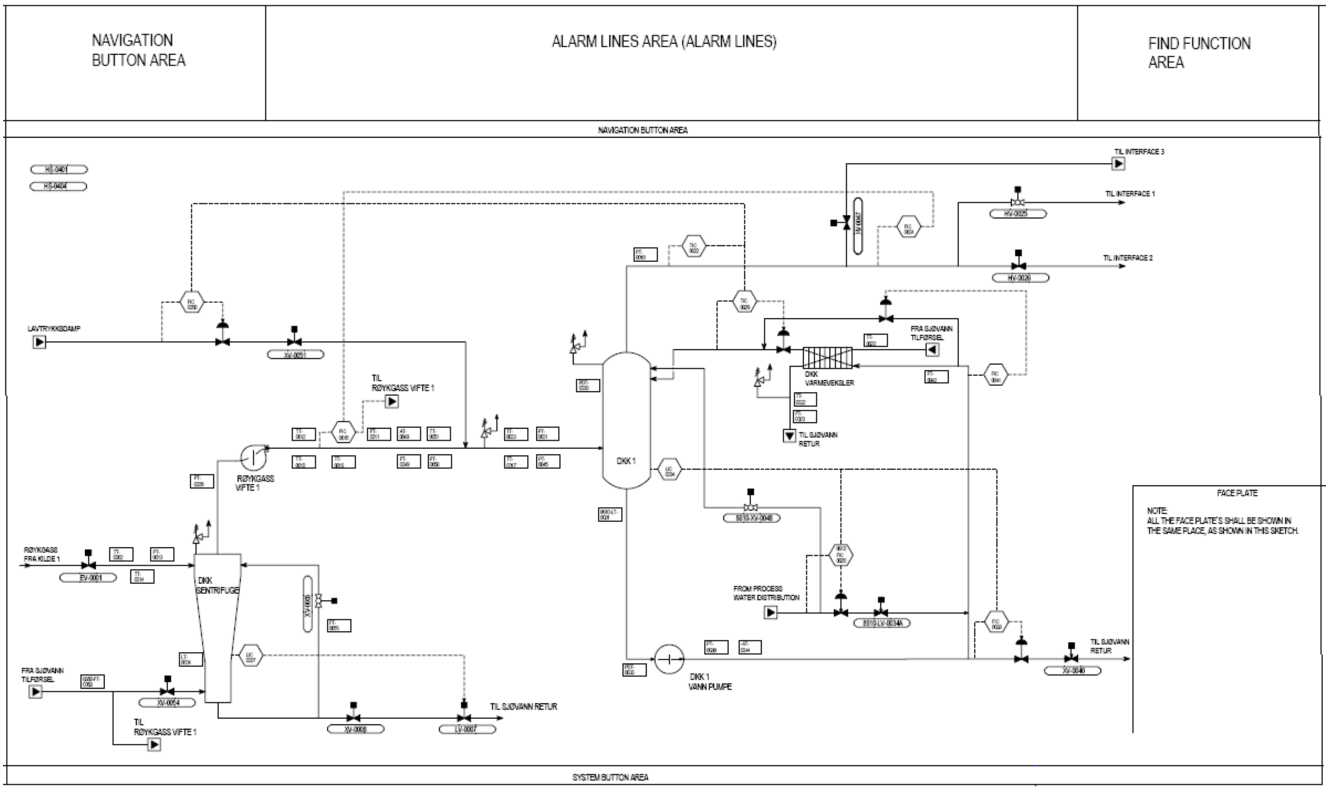


Figure 22: The Typical HMI-Sketch

Based on client rules all text in the HMI shall be on Norwegian. In the a copy of the sketch shown in figure 23, the main equipment and main flue gas line from source 1 in this sketch is marked with blue and English text is added to show the main equipments which have been noticed through the P&ID and SCD presentations in this report.

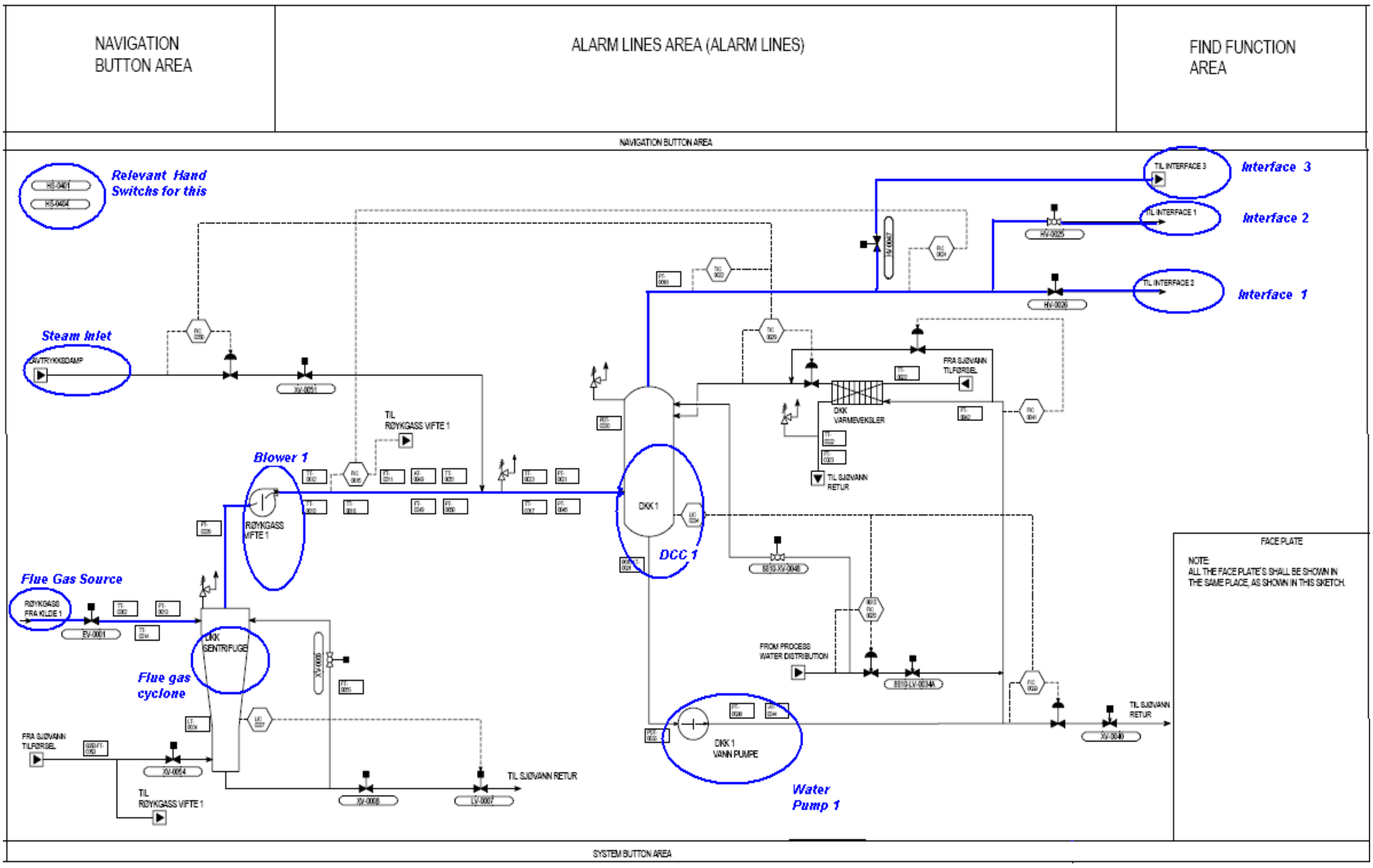


Figure 23: Typical HMI sketch (with English text)

The sketch was delivered to the SAS supplier with all the engineering documents needed for implementing of the typical HMI based on sketch. The documents delivered were:

P&ID's, SCD's, IPF &Control Narrative, SAS service description and the sketch. The figure 24 is the first HMI based on the sketch above.

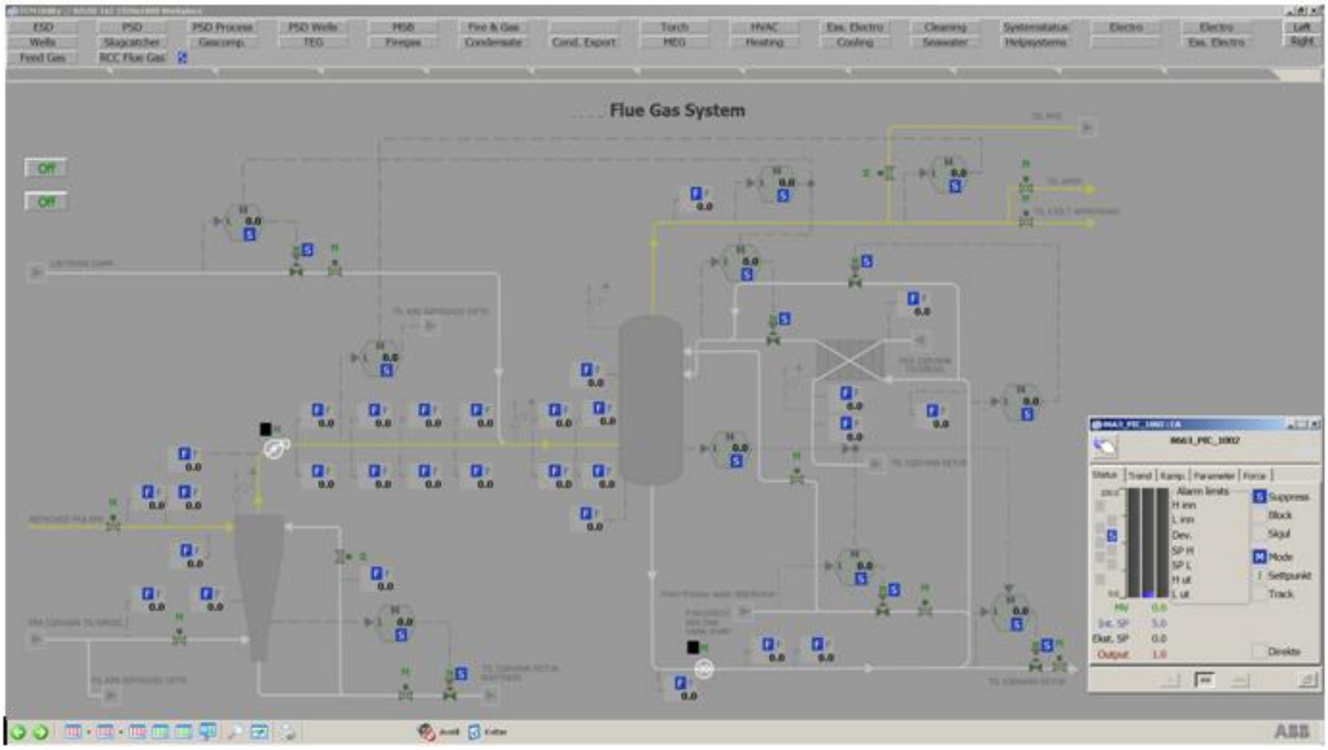


Figure 24: The first HMI based on the sketch

When the typical HMI were implemented, in my point of view the first V&V activity started.

The multidisciplinary design team including end-user thought a design review meeting discuses both the sketch and the HMI picture.

There were a lot of different problems which has been discovered through the first design review for the typical sketch. Many points which needed clarification were discussed.

The questions that the multidisciplinary team answered before the start of HMI development process were:

1. Decide the correct font size?

   Solution: The font size was decided based on the monitor size in the project. It was decided that the correct font size shall be used in the sketches.

2. Choose specific colors for different process media lines?

   Solution: The specific color was chosen for different process media based on TR 1212.

3. How the transmitters shall be shown?

   Solution: Different type of transmitter graphic was presented in the TR 1212, one was chosen as preferred but the other could be used if needed.

4. Should the sketches include tag number, or shall those reflect the HMI as much as possible?

   Solution: The HMI sketches shall reflect the final HMI as much as possible. Then it shouldn't be any other information included in the sketch but separate mark up sketch shall be delivered to the SAS supplier/programmer including tag items, line color and thickness and all other information needed.

5. How the Hand Switch graphic shall be shown in the HMI?

Solution: Beside of the graphic for Hand Switches which is shown on the typical sketch, it shall be included an information text to give enough information about the HS to operator.

6. How the Start/stop sequences shall be shown more useful for the operator?

   Solution: Normally start/stop sequences are shown in a face plate. Regarding to the complexity of some sequences in this project it were decided special HMI pictures shall be made for each sequence.

7. Which software shall be used for the HMI sketch design?

   Solution: Smart sketch or Visio can be used.

8. The process line thickness shall be defined for the software used for HMI sketches.

   Solution: 3 different thicknesses were chosen based on the TR 1212.

9. As shown in the typical sketch above, there is a special place for the face plate. It means that the face plates opens in this place first and if the operator wants it can be moved to the other places in the HMI. But the end-users involved weren’t sure about the idea of one main place for the faceplate.

   Solution: After that the reasons of the faceplate solution were presented to the end-users. The end-users confirmed that is a good design and they wish to use this solution.

10. Define where is needed to show a bar graph?

    Solution: It was decided that through the design review for each sketch the use of bar graph shall be clarified and used.

11. If the sketches shall show the real HMI as much as possible, how the information about process lines color, line thickness, bar graph shall be send to the SAS supplier or programmer?

    Solution: The HMI sketches shall reflect the final HMI as much as possible. Then it shouldn’t be any other information included in the sketch but separate mark up sketch shall be delivered to the SAS supplier/programmer including tag items, line color and thickness and all other information needed.

12. Are the service descriptions which have been written so far is correct regarding end-users opinion?

    Solution: The end-users shall give input for the SAS service description document which it is needed to be updated regarding their opinions and experience. (SAS service description is an specification engineering document regarding all text that can be used in the safety and automation system.)

And also other questions was clarified which is not included in this report. The main questions which have affected the HMI design development for the Flue Gas system-Source one is mentioned above.

After this general meeting, a plan was made for the multidisciplinary group to go through all the sketches. An action list were established to track changes and actions which different members of the group should implement and a check list were made by human factors responsible [21] for leading these meetings.

The general points of this check list for HMI-Sketch design review which have been used for each sketch are:

- **Purpose/ operator task:** Defining the goal of the sketch and go through the process scenarios which the operator has to perform.

- **Levels:** As mentioned in the page hierarchy philosophy in chapter, four levels are defined for each HMI. In this part of the check list the design group discusses which level shall be used for each Sketch.
- **Content:** Information presented in each sketch is reviewed by this point. Are all the instruments relevant for the operator task of the sketch is presented in the sketch? Also evaluation if anything should be added or changed, how the information shall be presented?
- **Organization/ structure/ space:** Presentation and review of different solution of the instruments and process lines and signals shown in each HMI-sketch.
- **Title / headings:** Based on the TR 1212, each HMI shall include a title. The review of the correct title is performed in this part of the check list.
- **Text/text location:** All the text and the text locations were evaluated under this point.
- **Language:** The language were corrected and checked in this point.
- **Lines:** Presentation of the process line and signals were corrected.
- **Margins:** Correct distance and correct margins of the elements were checked under this point.
- **New symbols/ issues not listed in the TR:** How to present elements which were not defined in the TR and to fine the symbols to use.
- **Other:** New issues for each sketch.

All the HMI sketch design review meetings were lead by human factors responsible from the engineering firm.

The participants for the HMI sketch-Flue Gas system-Source one were:

1. Human Factors responsible, one from engineering firm and one representing the client.
2. Automation engineer who has designed the SCD and responsible for the control philosophy of the system and basic concept design of the HMI-sketch. Programming engineer, representative from SAS supplier. In addition one Automation engineer client representative and SAS package responsible.
3. Two end-users representatives /operators.
4. Process engineer, responsible for the P&ID’s.

The first sketch made by the Automation engineer and the Human Factors responsible.

The sketches were presented to the multidisciplinary design group. Through the design review some actions were noted in the action list and implemented in the sketch.

The sketches were sent to the end-users and after their agreement the final sketches were ready for delivering to the SAS supplier.

For the four SCD’s and four P&ID’s represented in this case study , it has been made 3 HMI sketches, exclusive start and stop sequences.

This part of the system had 5 sequences and five HMI- sketches. Those sequences were very complex and it is not included in this case study.

The 2 final sketches for this system are shown in figure 25 and 26 below. The reason of choosing these two main sketches for this case study is that by comparing the changes between the typical sketch made as an example for Flue gas system Source 1at the start of the design process and the final sketch for this system, the improvements shows the effects of the multidisciplinary design process. And the other sketch that is shown in figure 26 includes special case for this sketch that is the result of the input from the design group.

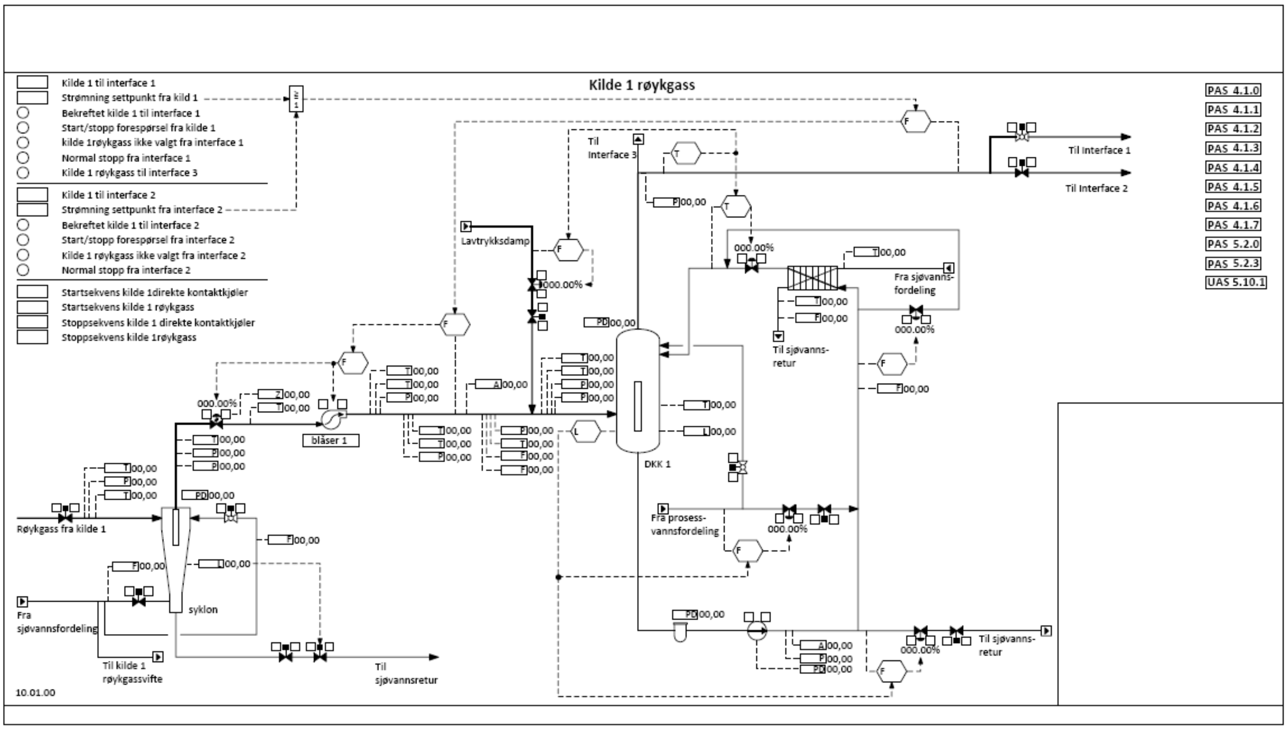


Figure 25: The final HMI-sketch for source 1

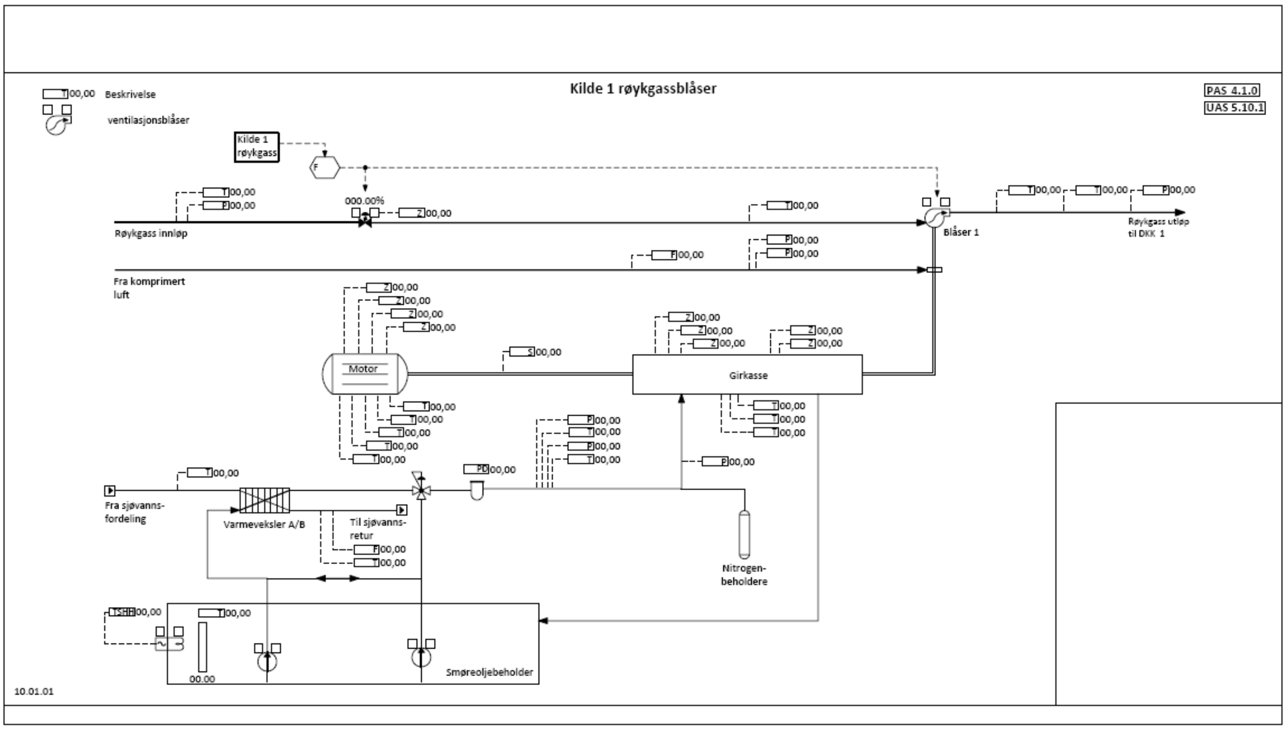


Figure 26: The final HMI-sketch for Blower 1

9 DISSCUSSION-HMI DESIGN PROCESS (STEP 1 TO 5)

Please be aware that this chapter reflects my opinions about the HMI design process so far and it doesn't include opinion from any parts included in this project/case study.

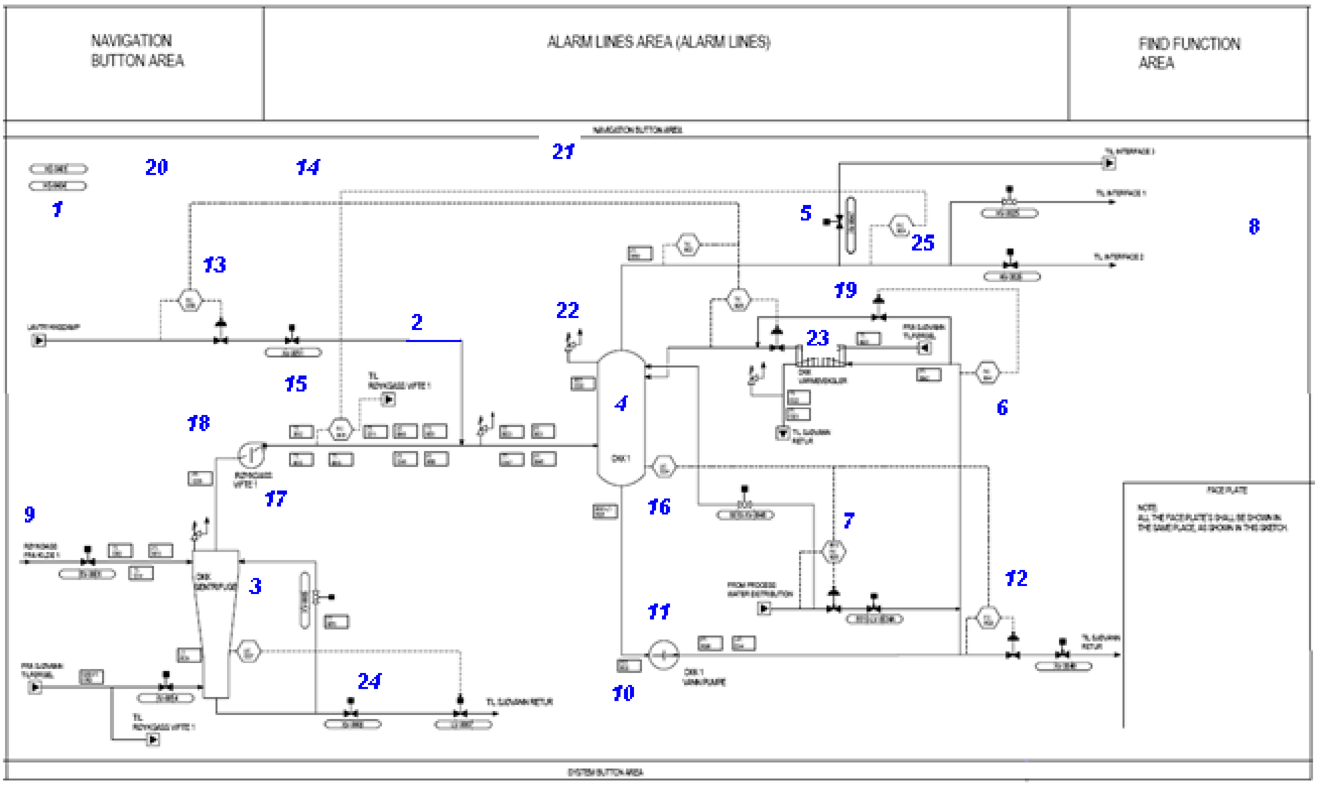
As a participant in this case study and an observant in the design review meeting for all systems some questions which I had in mind at the start of this report has been answered.. One of the questions was about the design process. How the design process can affect the HMI before start of programming?

To highlight all changes which were a result of the HMI design process figure 27 has been included in the next page. Figure 27 shows both the typical HMI sketch and the final HMI sketch for Source 1.

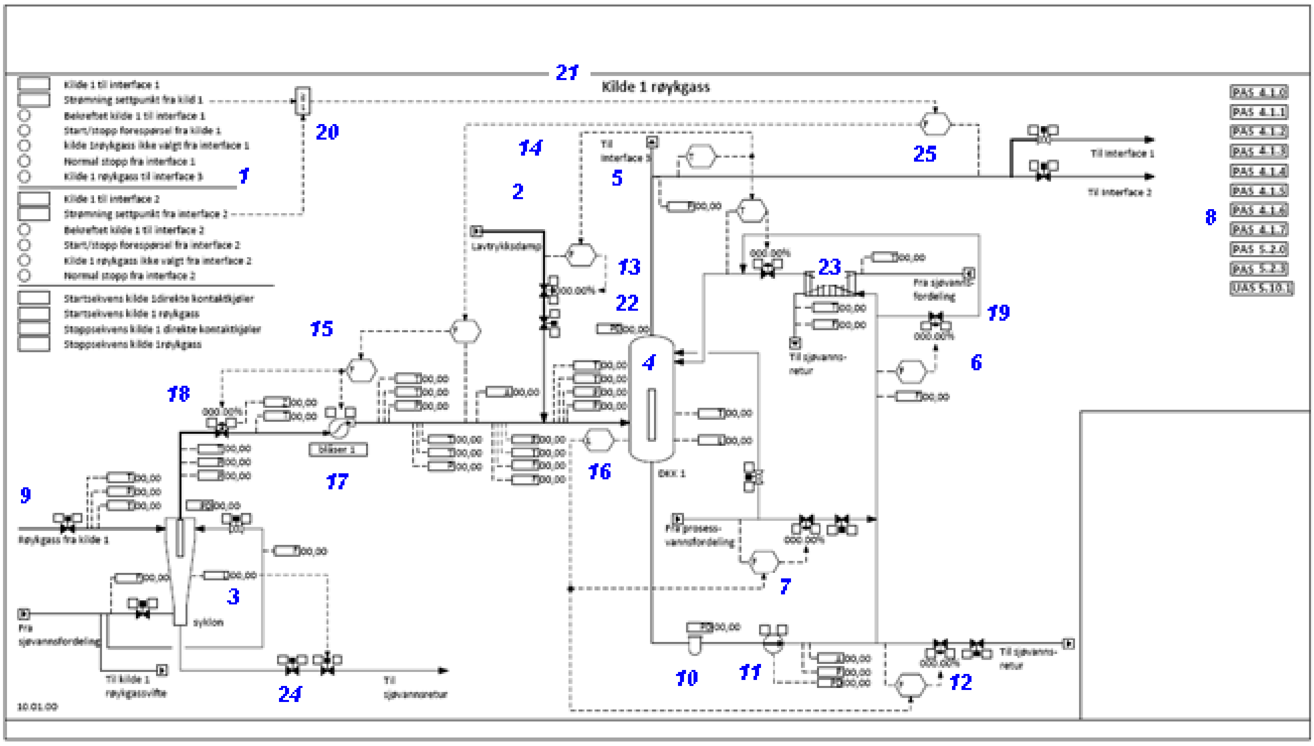
Each difference between these two sketches is marked with a number in both sketches to make it easier to understand how much this multidisciplinary design process has been effective.

The explanation of each number in the sketches in figure 27 is included after the figure.

The numbering of the changes is based on the actual points noted in the sketch design review. Because the author has tried to describe the actual design process and it is the reason why the numbering does not have any specific orientation. But each number is shown in the almost same place in the both sketches in figure 27.



The Typical HMI-Sketch for Source 1



The final HMI-sketch for source 1

Figure 27: Comparing the result for HMI-Sketch

As shown in the figure 27, there are 25 improvement point in this one single sketch.

It has to be mentioned here that the typical sketch were made in short time and at least 7 of the points were corrected if the designers had more than four days to make the typical sketch. But the rest of the improvements are in my point of view a direct result of the design group and design process.

Before making the sketch it has been meetings, with help of “brain storming” method, good ideas for the sketch were noted and implemented.

The sketch design review for this system started with presentation of the system PFD, SCD’s and P&ID’s for the design group and the presentation of critical situations regarding different process scenarios by the automation engineer/ SCD designer.

Then each point of the check list was discussed and all actions were noted in the action list.

The final result was the final HMI-sketch for source1. Explanation for Each number/change shown in figure 27 is included in this part.

1. The basic idea was to see how the HS graphic is shown. But as you can see in the final sketch a text were added beside each HS to make the operator job easier. Other change in this part was including all relevant interface signals which were important for the operator tasks. To be specific 10 interface signals were shown with graphic presentation and informative texts.
2. The steam inlet line was moved to center of the sketch to avoid crossing signal lines.
3. The title was moved and a bar graph included showing the level in the cyclone because of the operator task.
4. The title was moved and a bar graph included showing the level in the Direct contact cooler (DCC 1) because of the operator task.
5. The valve to interface 3 is moved to another sketch after discussing the operator task in this sketch.
6. The pressure regulator loop from controller to the valve was corrected, and the opening set point to the valve is included.
7. The flow regulator loop from controller to the valve was corrected to avoid crossing the lines, and the opening set point to the valve is included.
8. In the typical PSD levels were not shown because the designer weren’t decided where the levels shall be shown. Design group discuss that matter and by getting help from experience based of other projects and expert tips the PSD levels were included for all the sketches as it is shown in this sketch.
9. The text and text place were corrected (general number for all the text for process lines).
10. The element for Differential pressure was included.
11. Water pump symbol were corrected.
12. Flow regulator loop were corrected to avoid line crossing.
13. The control loop moved to the center of sketch to avoid line crossing.
14. As an effect of point 2 the signal crossing was avoided.
15. The cascade regulation of the set point for blower is more complete.
16. The level regulator place from controller to the other controllers (cascade control) was corrected to avoid crossing the lines.
17. A navigation button was included to connect this level 3 page to the relevant level 4 pages for the blower.

18. Part of the instrumentation from the Blower package HMI sketch were copied here to give a better overview to the operator regarding operator task.
19. The valve graphic was corrected regarding TR 1212 (general point for all valves) and the place for the valve is corrected.
20. A dynamic signal was included to highlight which set point from which Interface plant is send to the flow regulator for each scenario.
21. A title was included.
22. Pressure Safety valves (PSV) was deleted based those valves do not have any signal to the SAS system.
23. The title for Heat exchanger was deleted. The symbol was enough.
24. General for all valves and tag items: all tag numbers was deleted from the sketch and were included in the mark up.
25. Input and output signal sides were corrected to avoid crossing lines.

In the other final sketch represented in figure 28 two main improvement points was included.

1. All instruments in this point is shown in both final HMI-sketches for Source 1and Blower one. This improves the better overview for the operator task regarding start up of the blower and the start up of the whole system.
2. The navigation button was included for connecting this level 4 HMI to the belonging level 3 HMI.

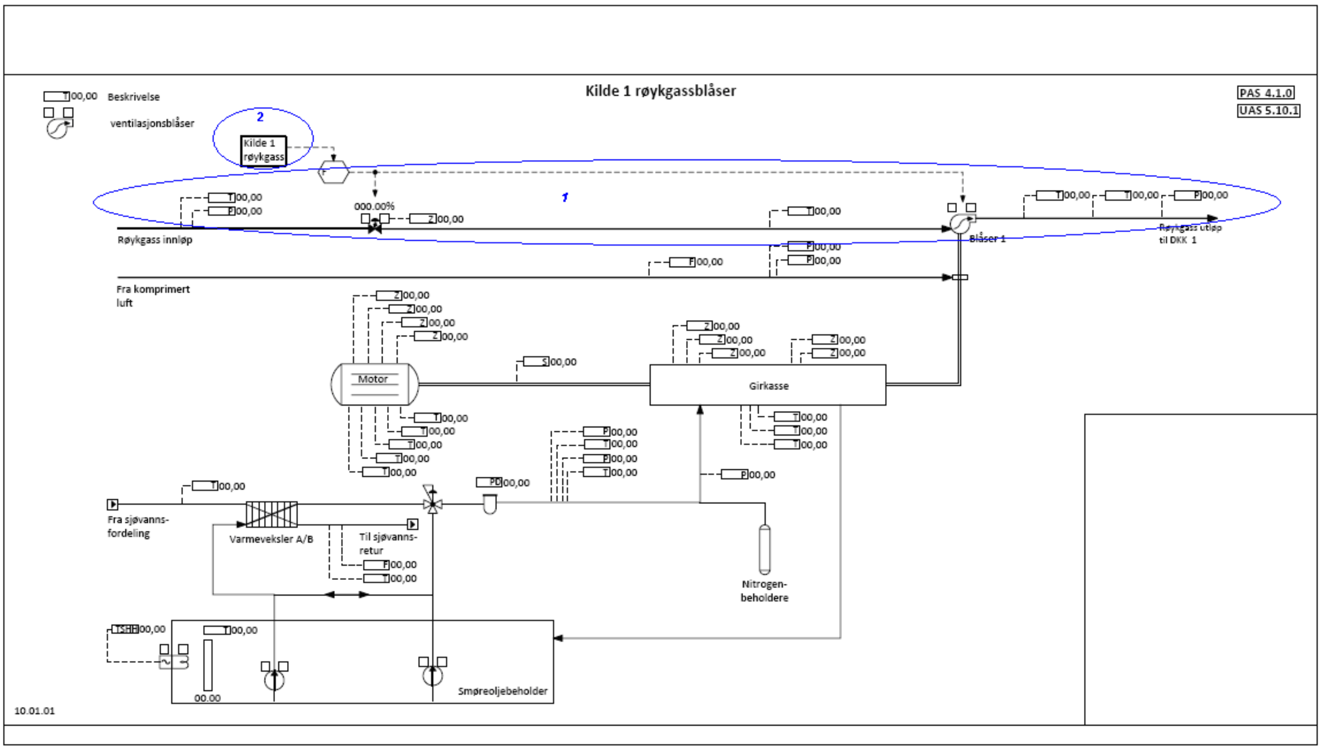


Figure 28: The final HMI-sketch for Blower 1(mark up)

In my point of view these 27 points of improvements for just these two HMI sketches present the affect of the design process for HMI design before the start of programming.

10 CASE STUDY- LARGE SCREEN DISPLAY

10.1 Introduction

The level 1 is defined for the LSD (Ref. Chapter 6.5). The overview page on LSD is shown permanently and no process control or system interaction is available in this level [18].

The LSD design can affect the other lower levels in the HMI design process. The HMI group shall discuss this topic and goals for LSD first before start of discussing other levels for the plant's HMI design.

As mentioned in chapter 6.8 the following design process describes a summary of the LSD design steps in this case study: (includes step 1 to 5):

1. Define the main goals of LSD in CR.
2. Define different Zones, define size of each Zone.
3. Operator Task/Define which operation scenario shall be supported by LSD.
4. Make a sketch.
5. V&V and deliver the final sketch to the programmer.

An important step in the design process is identification of the information that should be represented on the LSD. The content on the LSD has to be carefully evaluated during the design process with basis in the user's operational experience and process knowledge, and the technical information.

The Large screen display included two following zones, the first zone is safety, where
F&G area is shown and second zone is the process overview part of the LSD.
The LSD in was designed to ensure:

1. Attract attention on abnormal situation.
2. Overview on entry/"Status at glance"
3. The visual appearance of the displayed objects reflects the importance.
4. Overview, freedom to move for operator under normal circumstances.
5. Main operation scenarios shall be supported by the displayed objects.

Figure 29: Main CR LSD and Operator stations (Type EOW-x3, delivered by CGM)

The LSD in main CR as shown in the picture above consists of 3, 52" LCD displays.
The following diagram Figure 30 illustrates the main zones for the LSD in CR. In this case study a short summary about the safety zone is included and the main process zone is described in details shown with a circle in the figure 30.

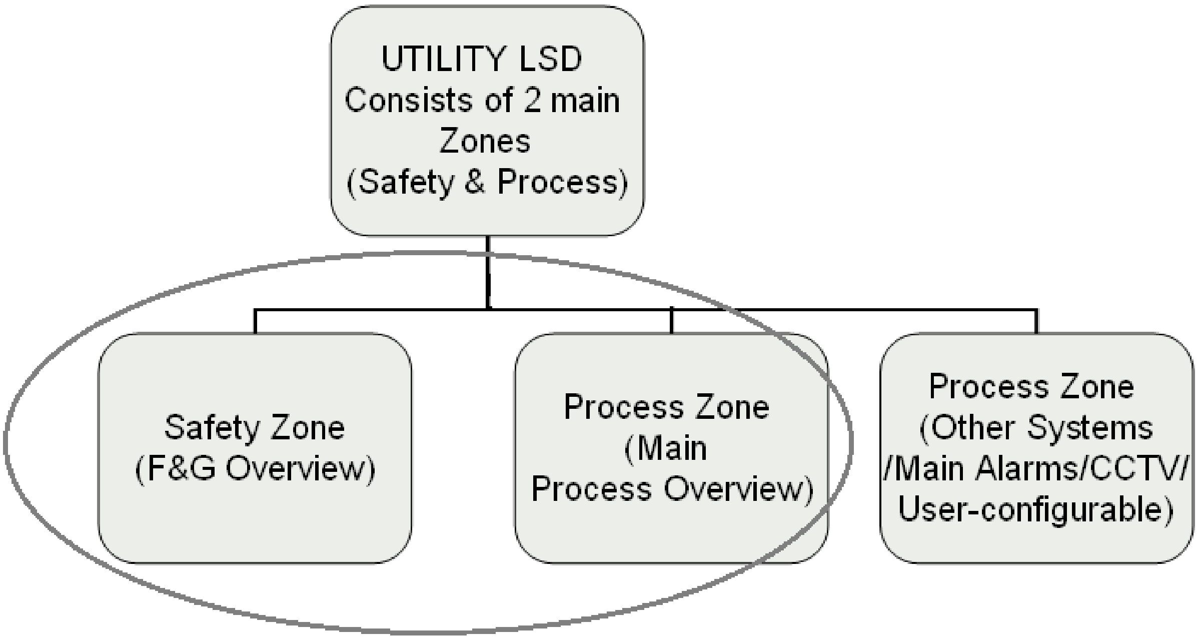


Figure 30: The Main Zones –LSD

10.2 Design process for the LSD

The first step was to specify the following questions:

- Dose it needed LSD in main CR?
- Who shall be part of the multidisciplinary design group for the LSD design?

The team consists of automation and human factors discipline with help from other relevant disciplines defined the goals for a potential need of the LSD for the control room.

The goals and different zones for LSD were defined and discussed at first and then the technology was chosen for the LSD solution in this project which consists of 3, 52" LCD displays.

These activities take place long while before the time when the project had the opportunity to involve the operators/end-users.

But as mentioned, the design group decided that the same design process should be used for the design of HMI for all zones of the LSD as the HMI process design for the operator work stations.

As mentioned the technology had to be chosen first but the end-users were involved in the design process of the context in LSD from the first step.

The basic concepts of the zones deviation were introduced to the multidisciplinary design group including end-users. When the whole group were agreed on the basic concept (goals and zone deviations) the process for sketch development were started.

Safety Zone:

Because of the confidentiality of the details represented in safety zone the sketch for this part of the LSD is not included. But the affects of the design process are included in this part.

After that the design group was agreed on the basic concept for the safety zone the first sketch was developed.

Through the design review meeting and the check list mentioned in chapter 8, a new sketch was developed. The end-users were agreed on the final sketch and the sketch was delivered to the SAS supplier for programming.

The following points were corrected by the design group and the multidisciplinary design process for the sketch to ensure that the goals mentioned in chapter 10.1 is achieved:

1. The symbols on LSD safety zone shall be the same as used in the operator stations.
2. Fire and Gas detection deviations areas were re-designed to give a better overview regarding operator tasks.
3. Including the CCTV camera symbols at the correct place.
4. Corrected the escape routes graphic in the sketch.
5. Correcting the texts.
6. Add descriptions for ESD levels not just the ESD level number.
7. Included alarm text for F&G, and the text to be displayed at the actual area when an alarm is activated. It should clearly display which type of gas is actually released.
8. Wind direction symbol shall be exactly like the operator stations.
9. A new display element shall be made by end-users opinions.
10. Correcting the pipe rack graphic.
11. The design group decided to include 2 CCTV graphic in the Process zone part of LSD vertically on the left hand side of the main process overview.

It has to be mentioned here that the software used for safety LSD sketch was Visio.

All the other sketches were made by using Smart sketch software.

Process zone (main process overview):

A basic concept was developed by HF and automation engineers. The concept was based on the operator task regarding the main system and the interface plants. After that the design group was agreed on the basic concept then, the process for first sketch was started.

Through the design review meeting and the check list mentioned in chapter 8, four different basic sketches were developed.

The next step was to introduce these four different ideas to all the members in multidisciplinary design group. The group was agreed that 2 of these concepts shall be used for the final sketch review and the others are not going to be used.

The basic scope for this part was that the Flue gas system has two separate main delivery process line for delivering of flue gas to five different Interfaces. And it was very important for the operator to have overview about all the five plants. Then an overview process picture can help the operator to get the best overview of the whole plant at any time.

As mentioned in part 10.1 the main goals for LSD were 5 points, here is discussed how this five goals were achieved for this part of the Sketch for LSD main process overview zone:

1. Attract attention on abnormal situation.
   The graphic shall show if any ESD, PSD, Normal stop has been activated for the main instruments, the flue gas system or from the interface plants and the flue gas sources at any time.

2. Overview on entry/"Status at glance"
   All main instruments which have effect on the main system shall be included in this sketch. And also this can be useful at the shift change between different operators.
   The interface plants graphic element shall be programmed as an element supporting different interface signals and process or emergency situations.

3. The visual appearance of the displayed objects reflects the importance.
   It was decided the graphic elements basic presentation shall be shown like the elements in the operator stations, but a frame around the graphic element shall show different scenarios with color matched for the same scenario in the process display to avoid any misunderstanding.

4. Overview, freedom to move for operator under normal circumstances.
   The size of the elements shall be customizing for the CR.

6. Main operation scenarios shall be supported by the displayed objects.
   The operation scenario shall be supported by the graphic to give information to operator about which process scenarios are in operation.

The tow different sketches were developed based on the input from the design group. And at the final review one of the sketches were chosen to be delivered to SAS supplier.

Tthe final Sketch for the main process overview in LSD is shown in figure 31.

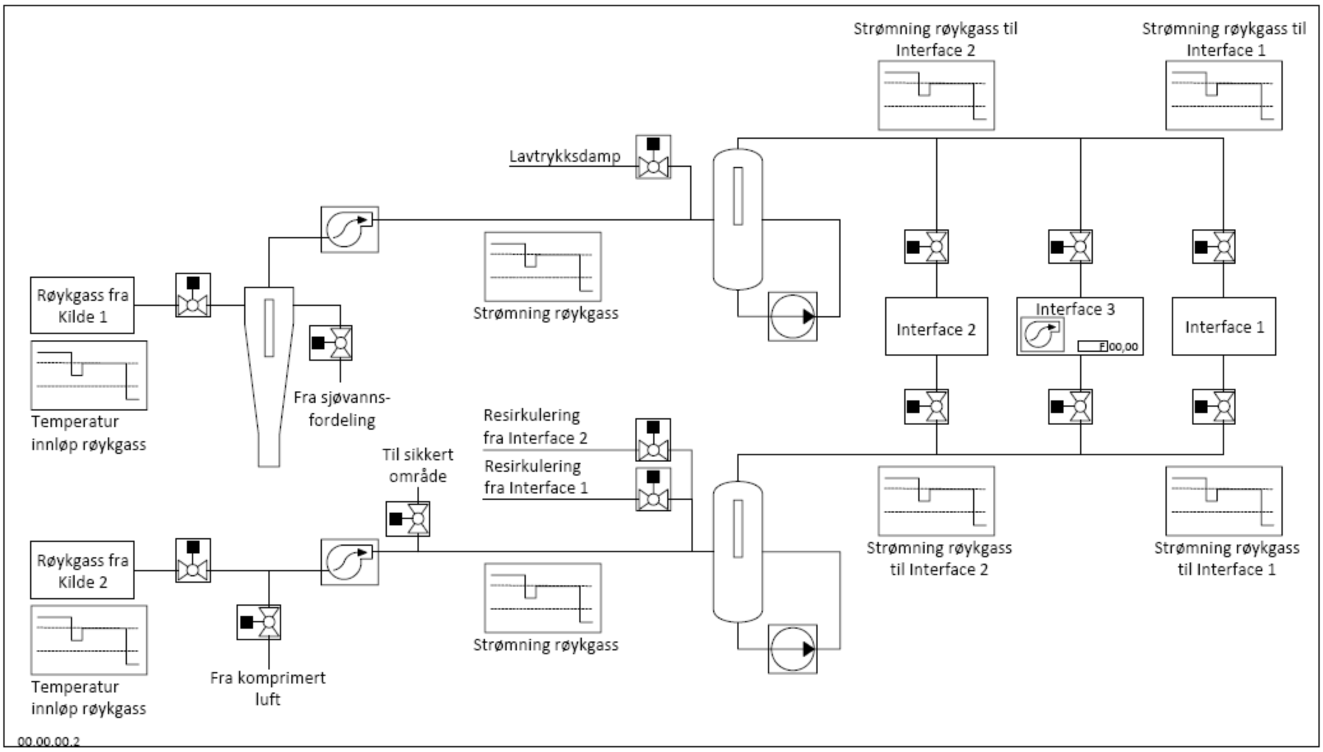


Figure 31: Final HMI-Sketch for LSD-Main Process Overview

This single sketch in figure 10.2-1 for the main process overview is based in four different process flow diagrams, eight piping and instrument diagrams and eight system control diagrams and four process flow diagrams.

The graphic supports ESD and PSD related to the instruments shown in the sketch and also support nine different process scenarios (including main part of start/stop sequences) and five different sub process scenarios and 2 main and critical maintenance process scenarios.

To give a better understanding of the process scenarios the figure 32 are included here to show the complexity of the main system for the plant. Different scenarios are shown with different colors.

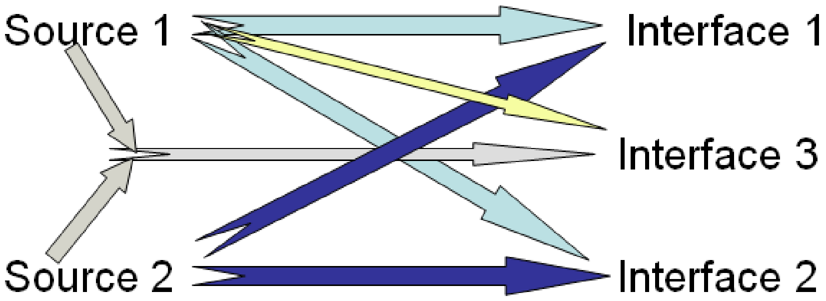


Figure 32: Different process scenarios in case study

The last LSD sketch for process zone which includes the CCTV and overview for other relevant process systems is not included here, because the other process systems except from the flue gas is not part of the scope in this case study. But the design process for the last part was the same as described for the main process overview sketch.

10.3 Discussion LSD-HMI Sketch development

Please be aware that this chapter reflects my opinions about the HMI design process so far and it doesn't include opinion from any parts included in this project.

The main cases which were very helpful for the whole the design process were:

1. Multidisciplinary meetings before choosing the technology for the LSD.
2. To make a basic concept and goals for the in formations needed to be part of the LSD before choosing the technology.
3. Use of experience from the other projects was very helpful to be able to present a correct overview in the LSD.
4. During the sketch reviews, the LSD sketch review was one of the last activities. Because the design group had been involved in the sketch reviews for all systems in the plant. This helped for the understanding of the concept for LSD. Also it helped to correct the information presentation because of the total understanding of the whole plants during the work stations sketch review.
5. Since there were no standard defining symbols or elements, the whole idea for these sketches was customize with the end-users input from the start.
6. New symbol presentation was developed by the design group. Instead of the traditional way of design were the symbols are made then the end-users are able to affect the design.
7. Give the opportunity to the whole design group for four different concepts by representing many different sketches at the first step, this helped the design to be more related to the goals of design and more related to the operator task and function in CR.

Figure 33 show the connection between the main process overview sketch and the PFD and SCD and P&ID's mentioned in chapter 7. The deviation in figure 33 shows the SCD's in red, P&ID's in blue and PFD in green just for the flue gas process scenario from source one.

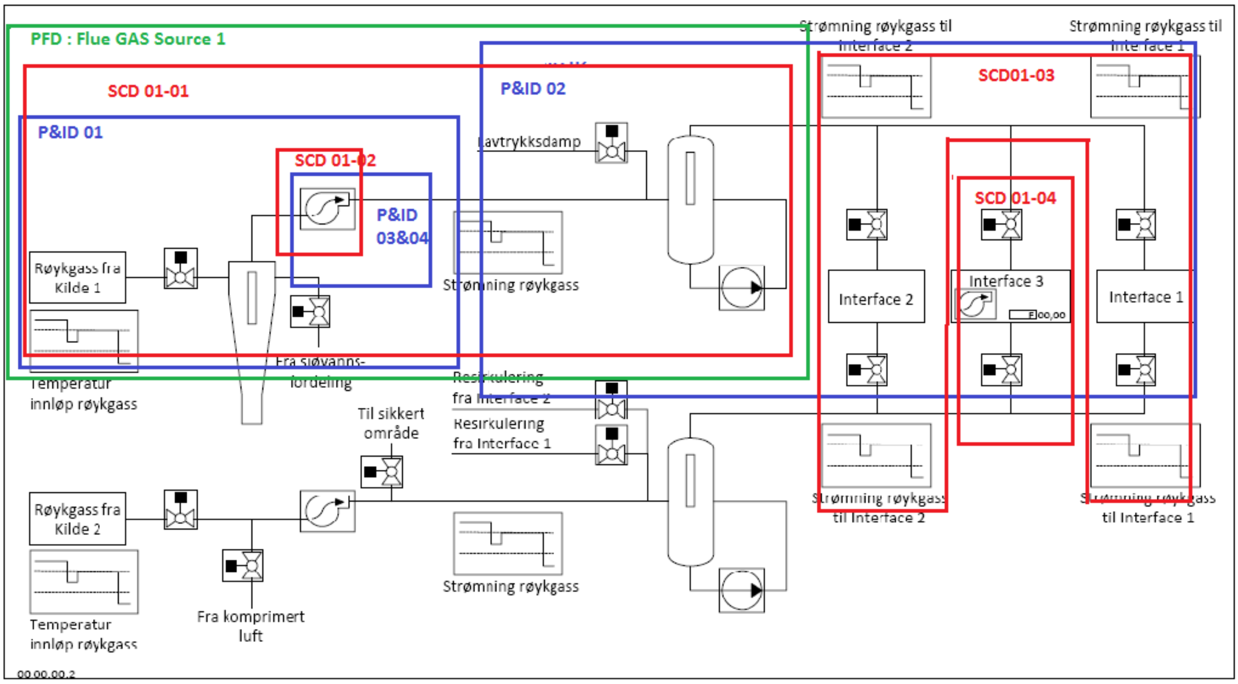


Figure 33: PFD, P&ID's and SCD's in LSD

11 EMAIL SURVEY

11.1 Background

En email survey was developed regarding part of the research questions for this report in spring 2010. The survey was send by email to 46 Automation and Human Factors engineers. The result presented in the next chapter is a presentation of the 24 who answered the survey. 17 automation engineers (6 different engineering companies and 2 SAS supplier companies) and 7 human factors engineers (3 different companies) have participated, the answers reflects personal experience of the participants and not their companies idea.

During the start of this report, some engineers asked me about the topic of this report, the reflections were very interesting. Some with HF background was surprised that an automation engineer wants to right a report about HF/HMI challenges bases on the ISO 11064; in their point of view the ISO was just relevant for HF. And in the other side some with automation background commented that ISO 11064 is an HF standard and wondered why I have chosen this topic.

In chapter 11.2 the result of the survey is included. Under each question it is explained why the question was included, represent the answer from HF and automation separately for each question and the additional comments from the participants.

11.2 The Survey and the Result

The result of questions regarding background of the participants is shown by a diagram for each question.

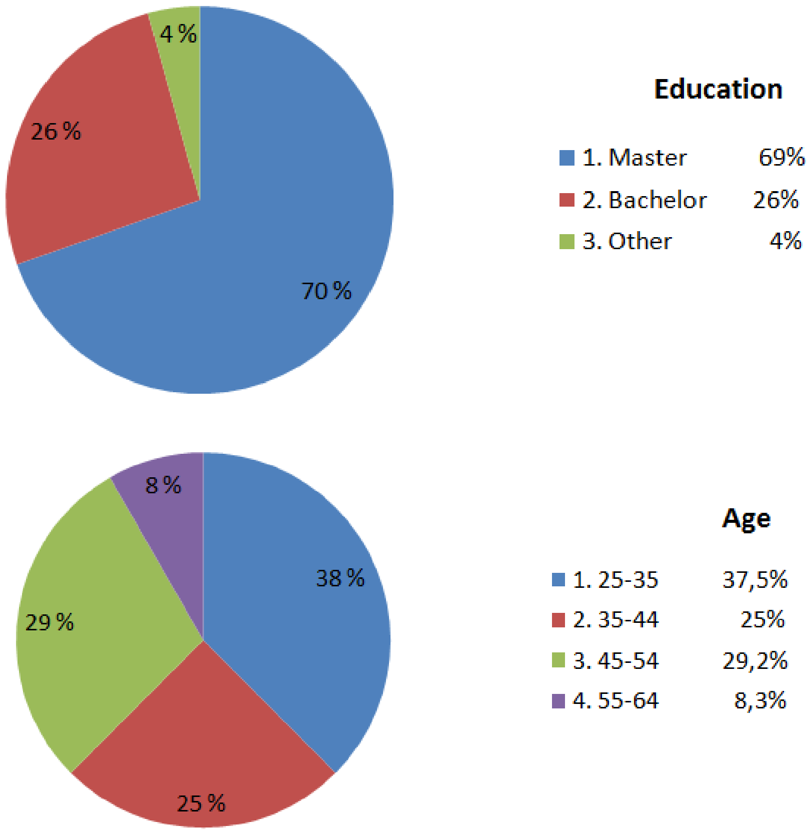


Figure 34: Education and age background

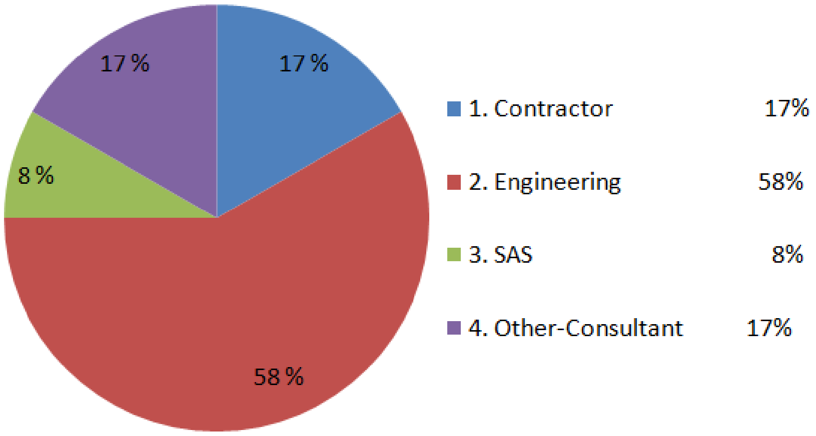


Figure 35: Field of work

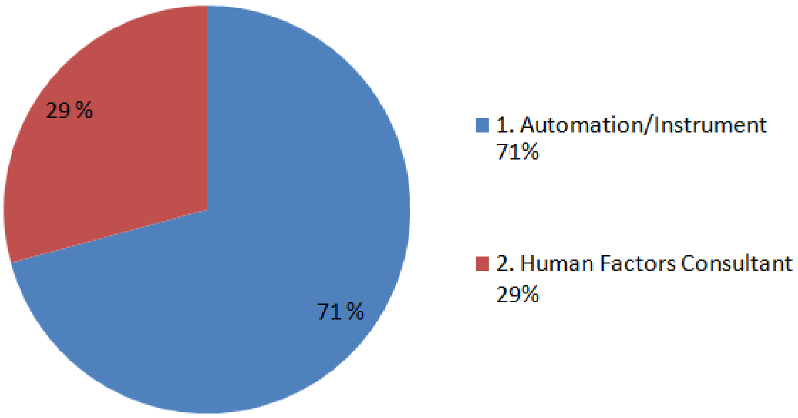


Figure 36: Current position

As shown in the figure 36 there are 29% of participants with HF background and the rest automation. Based on the case study in the sketch meetings from engineering team in average 1 HF and 3 automation engineers were involved in the design process. Regarding the involvement of the different specialties in the case study the total amount of answers sounds reasonable to rely on.

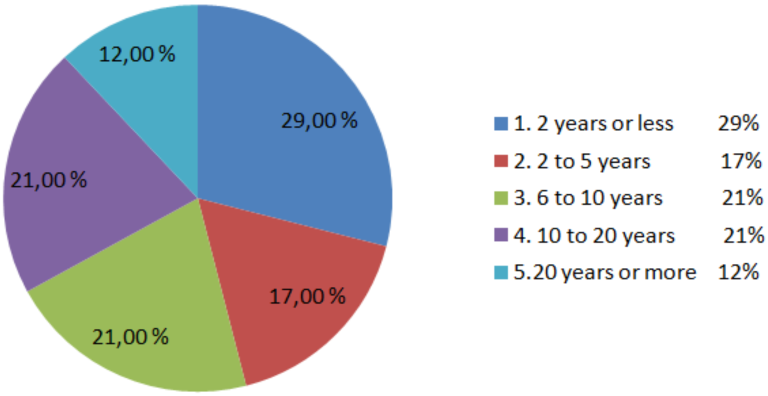


Figure 37: Experience in current position

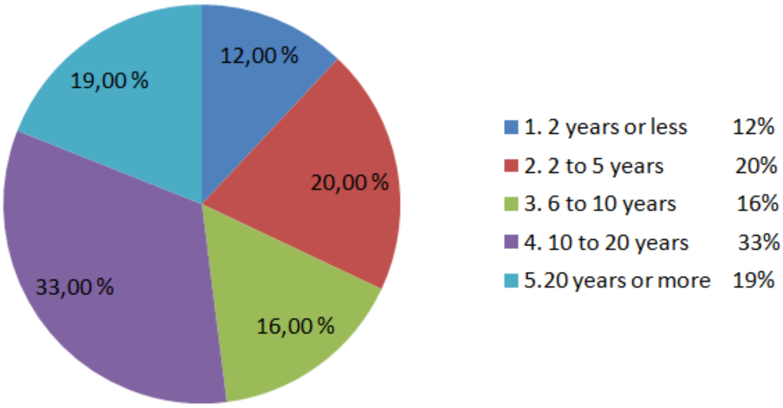


Figure 38: Experience in Oil and gas industry

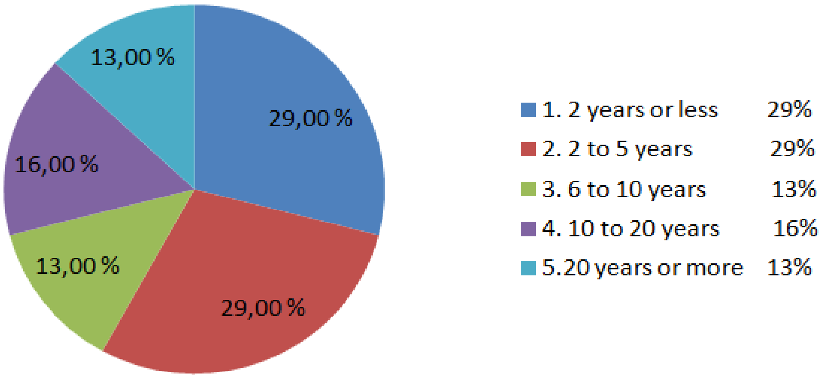


Figure 39: Experience in HMI design

It has to be mentioned that for the question regarding the figure 39, the question has not been very specific and the answers does reflect both the direct and indirect involvement of the participants in the HMI design related work.

Questions:

The second part of the survey was the main questions which are included here. The reason of why the question is included under each part. The answer from HF and automation are shown separately and some additional comments from the participants are also included under each part. The scenario is the design of an HMI for a process system for a total new plant (example an Instrument air system or Flue gas system….etc). Imagine the project has two main parts, FEED study and Detail engineering. The design of Safety and Automation system (SAS) is mainly done in two parts during detail engineering. First part is done by an engineering company and based on their work the vendor of the SAS system implement the HMI. A short discussion about the answers is included to summarize the answers given for each part.

11.2.1 Start of the HMI design process

Where in the life cycle of a project the design process of HMI shall be started?

Alt.1 during Feed Study

Alt.2 Start of detail engineering

Alt.3 During detail engineering when the last version of process flow diagrams(PFD), system manual, P&ID's and the SCD's are issued. (Before delivering the documentation to the SAS supplier)

Alt.4 As the same time when the SAS supplier starts making the HMI

Alt.5 others, please explain

This question has been included because there are different practices regarding the start of HMI design based on the contracts in different projects. Also if it is specified in a contract when the HMI design process shall start, the quality of the first documentation about the scope of work and planning for the activities is depended on the person responsible for these activities.

This question was included to highlight the verity of the answers which shows that each of the participants has experienced different practices. Also to show that it may need more research about separating different activities in different part of a project's design life cycle.

The fallowing diagram (figure 40) shows the response to the questions by automation engineers.

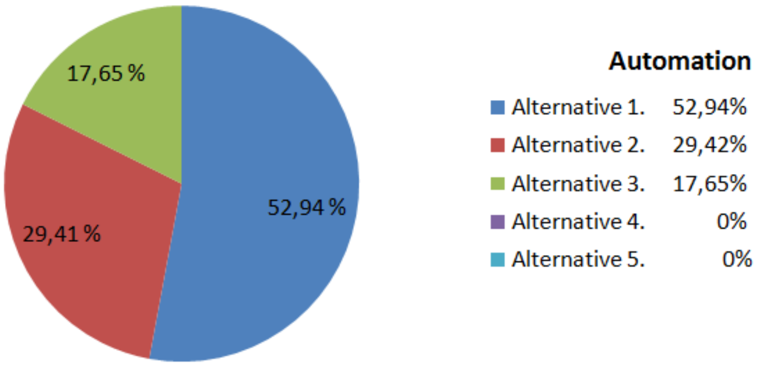


Figure 40: Automation response about the start time of the HMI design process

Attached comments are given by the automation engineers for the question above:

1. The concept used as basis for HMI design should be settled in feed study (The development of the HMI specifications/requirements.)
2. Basics for HMI philosophy should be started in the FEED study.
3. During late phase of a feed study, a total overview of the process can be obtained. The total process overview can in this phase already be divided into VDU pictures, chances for major changes in the process will probably not accrue.
4. During detail engineering is ok, but not until the last version of the documents is available (It’s too late). HMI detail related work should start after IDC (70% finished engineering) revision of the documents mentioned are published.
5. It shall start during feed study based on that the HMI may affect SAS configuration and sometimes also instrumentation level.
6. For a unique HMI, the HMI process should be started pre-contract. As part of the offer, and started during feed study. In this scenario the HMI has to rely on the SAS system, and it’s capability to implement HMI functions. HMI costs can be reduced by having SAS systems take into consideration regarding HMI limitation and capabilities.
7. At the start of detail engineering is too early for detail work and after the documents needed are issued is too late.
8. It is important to settle philosophies needed early during feed study.
9. It is an advantage to start early. However, there is no point in starting the HMI detail design process too early, because the design process requires an amount of maturity on the project.

The fallowing diagram shows (figure 41) the response to the questions by HF engineers/specialists.

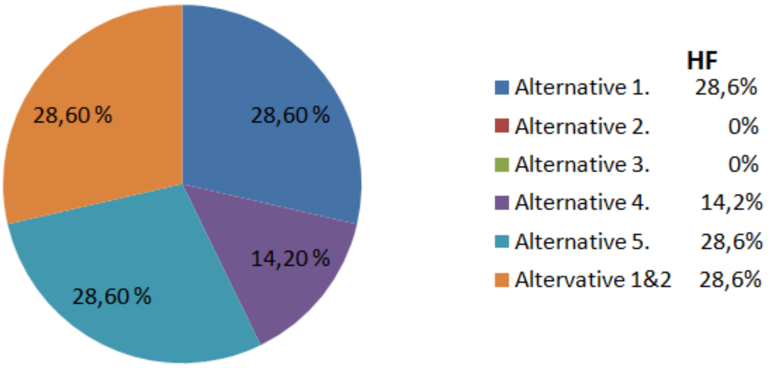


Figure 41: HF response about the start time of the HMI design process

Attached comments are given by the HF engineers for the question:

1. At the start of project. Develop goals philosophies and the basics.
2. Detail display design to be conducted in detail engineering. However scope, definitions, requirements, philosophies should be established in FEED study.
3. Principals should be agreed early in detailed. HMI for Individual systems shall be started when basis documentations are available. But not until the last version is available, it is too late.
4. The earlier, the better. The design starts with a philosophy, where goals, high level principals etc. are described. This has to be done prior to the FEED study. It can be called “definition phase” regarding the HMI design.

Discussion:

The most important similarity in the answers from both disciplines is that over 50% are agreed on the start of the HMI design process in feed phase, and that the basics shall be in place when the FEED study is finished. But there is small agreement between them regarding the detail design process.

There is one comment that includes” there is no point in starting the HMI detail design process too early”. In my point of view based on experience from case study this is very important to start the detail HMI design in correct time. Because by starting the design process without enough information about the functionality of the system, the definitions of operator tasks are not complete. It can lead to a re-design process of the HMI.

11.2.2 HMI engineer

What is your definition of an HMI engineer in real project life cycle (not just in theory) for HMI design process in oil and gas industry?

Alt.1 Human factors specialist

Alt.2 Automation engineer (designer)

Alt.3 Automation/programming engineer

Alt.4 All mentioned above and operator representative as a multidiscipline design team during the design process

Alt.5 others, please explain

This question is included based on a comment from a HF expert. First time when I wrote a text where the words “HMI Engineer” was used, one expert involved in the HMI design asked me about what is the definition of an “HMI Engineer”? In my point of view this question leads to the HMI design process and can show to those who define an HMI engineer by one type of specialty that HMI design in the oil and gas industry involves many different engineering fields and it can’t be define by one field. So who is an “HMI Engineer”? Is it a group of different specialties or just one specialty can define a “HMI Engineer”?

Answers:

The figure 42 shows the response to the question by automation engineers.

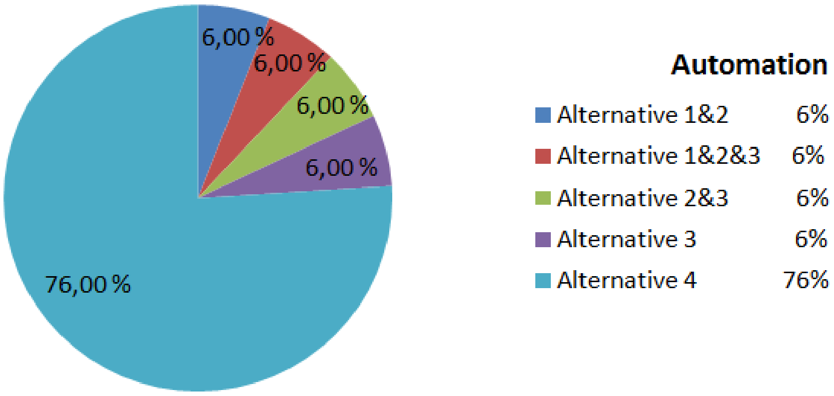


Figure 42: Define an HMI engineer- Automation answers

Attached comments are given by the automation engineers for the question:

1. “*I see the HMI engineer as the person who is actually implementing the HMI requirements*”.
2. For alternative 4: They carry out different tasks. The first should give the demands to the philosophy, the second should give the demands to individual systems and the third should implement the HMI.
3. One of those who chose the alternative 1&2&3 has given the fallowing comments. “*I do not consider the operator as a HMI engineer. Operators do transfer experience and do influence the HMI, but are not decision makers.”*
4. In order to obtain a good result, all disciplines above need to work together. Engineers tend to have limited knowledge on how operators perform their work, and what’s important to them to perform their everyday tasks.

The figure 43 shows the response to the question by HF engineers/specialists.

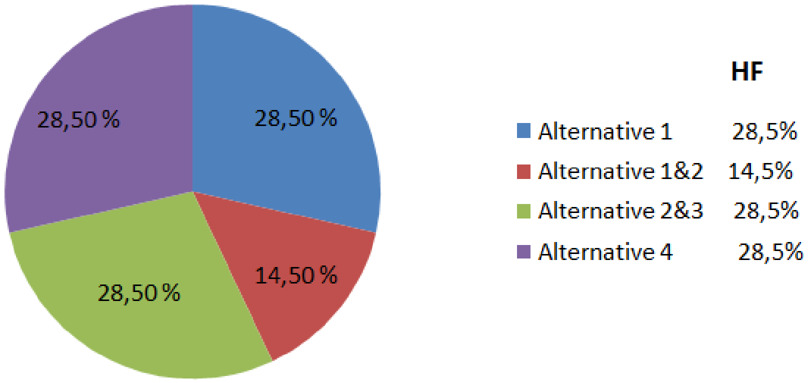


Figure 43: Define an HMI engineer - HF answers

Attached comments are given by the HF engineers for the question for this chapter:

1. One of the participants who have chosen alternative 2&3 includes that he regards to HF specialist as an advisor or facilitator, not as HMI engineer. Also end-user is essential to contribute with operation experience and knowledge and operator representative group might consist of different technical disciplines.
2. One of the participants who had chosen HF specialist as an HMI engineer mentions that *"It must be a multidisciplinary design team with essential competence covering HF, Instrument, operation, SAS and process as required, HF provides the interface knowledge, interaction and systematic approach".*
3. Another comment was that there is a difference between *"how it is normally done"* and *"how it should be done". "Too many projects fail because the suppliers do it all themselves and the answer should be change to all mentioned above".*

Discussion:

Based on the answers from automation and HF, it is clear that each of them has their own opinion about who is an HMI engineer. During the HMI design process these two groups should be able to work together and be agreeing on a work plan. In my point of view if HF and automation has two different opinion about the definition of the responsibilities each of them shall have through the design process then this can lead to fail of the process and affect the final product.

Based on the case study, regarding information presentation of the HMI for the flue gas system, just only 3 automation engineers who was involved in the design of SCD's had enough understanding about the information deviation for the HMI sketches. The HF roll through the design of the sketches was very important to give input about all the relevant HF criteria's for the sketch but regarding the information (tag items for each sketch) the automation was the only group who could suggest ideas for this part.

Based on the work in this report it is wrong to use the "HMI engineer" expression because HMI design in the oil and gas industry shall done be done by a multidisciplinary design team and the correct expression in my point of view is "HMI engineering group", which consist of different specialties.

11.2.3 Engineering documents needed for HMI design Process

Which of the following choices are correct for at the HMI for process pictures shall be based on? (More than one option can be chosen)

Alt.1 Process Flow Diagrams (PFD)
Alt.2 Process and Instrument Diagrams (P&ID)
Alt.3 System Control Diagrams (SCD)
Alt.4 mainly based on operator task and also use of all documents mentioned above to get a better understanding of the operator task.
Alt.5 Operator Task
Alt.6 Operator Task and Logic
Alt.7 Others…

The reason of including this question has been to find out which of the documents mentioned above has been useful for the HMI design based on the participant's experience and knowledge. And it shall be noticed that ISO 11064-7 does not include any detail information about which engineering document shall be or shall not be used for HMI design.

Answers:

Automation engineer's answers for this question is shown in the following diagram, figure 44.

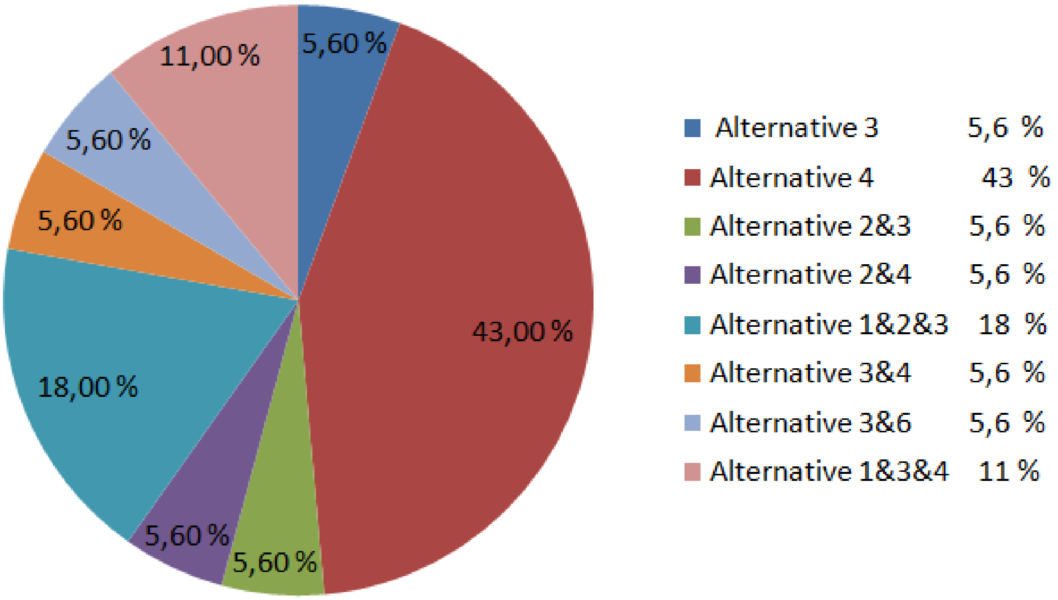


Figure 44: Basic engineering document needed for HMI design - Automation answers

The following points are the comments given by the automation engineers who participated in the survey.

1. There should be a one to one relation between SCD and HMI in order to ease operator readability in stressed situations.
2. The basis for programming should be common document focused on functionality. The closes document is the SCD, but it should be adapted to the operator task.
3. One of the automation experts who had answered alternative 1, 3 and 4 includes that the same case should be applied for HMI for the emergency shutdown, process shut down and the electrical pictures.

Figure 45 represent the response to the question by HF engineers/specialists.

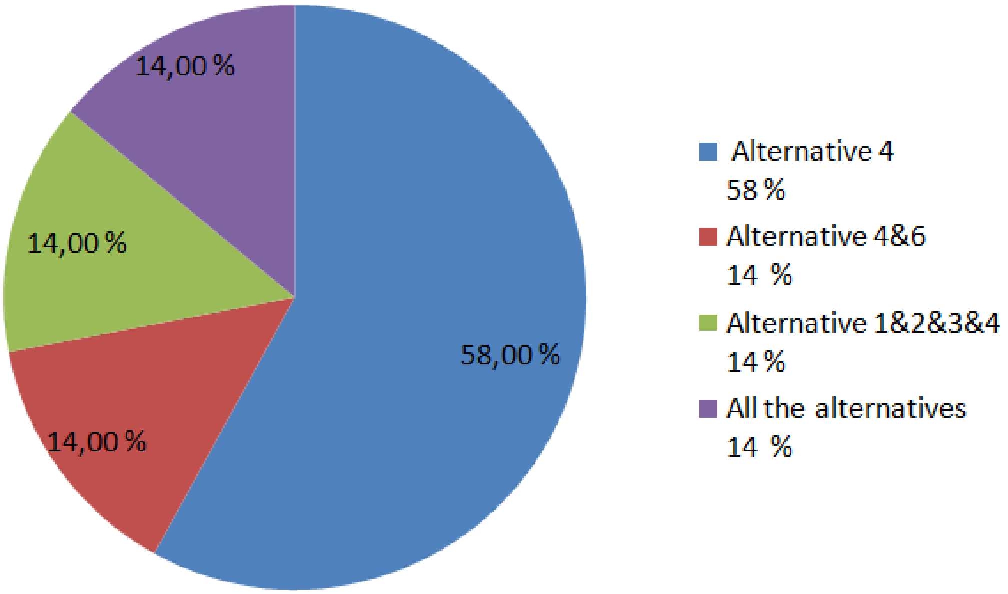


Figure 45: Basic engineering document needed for HMI design - HF answers

Attached comments are given by the HF engineers for the question for this chapter:

1. All relevant documents should be used. The goal of design should be design for optimizing operator task performance, i.e. design of human perceptual and mental abilities.
2. Process engineers design the P&ID and Instrument/automation design the SCD but neither of these are based on the operator task. But the information from these documents they contain is necessary for HMI design.
3. A good process HMI shall support the operator-nothing more, nothing less. The operator may need a view of process, instruments, controllers but the basics are the tasks.

Discussion:

58% of the HF specialists/engineers and 43% of the automation engineers has chosen the alternative four, “HMI pictures shall be based on the operator task and also to use all the documents mentioned to get a better understanding of the operator task”.

Based on the work so far in this report the alternative four is the best answer, because the PFD can help the designers to get a total overview of the system, the P&ID can help the designers with giving the information about the real installation details and the SCD’s give information regarding control system and operator task in control room.

But by comparing the figures 44 and 45, it is clear that there is too many different opinions about the use of engineering documents needed for design process.

Also regarding teamwork between the HF and automation during the HMI design process the lack of standardization is clear. In my point of view a guide line and more research is needed to give a better guide line about this question.

11.2.4 Multidisciplinary design group

Who shall be part of a multidisciplinary design group in the HMI design process? (More than one option can be chosen)

Alt.1 Automation/design Engineer

Alt.2 Automation/ Programming engineer

Alt.3 Operator / Operator representative

Alt.4 Process Engineer

Alt.5 Safety Engineer

Alt.6 Human Factors Specialist /Engineer

Alt.7 Human Factors, Automation (design and programming), and Operator are the main design group with help from other groups mentioned above when it is needed.

Answers:

Automation engineers answers for this question is shown in the following diagram in figure 46.

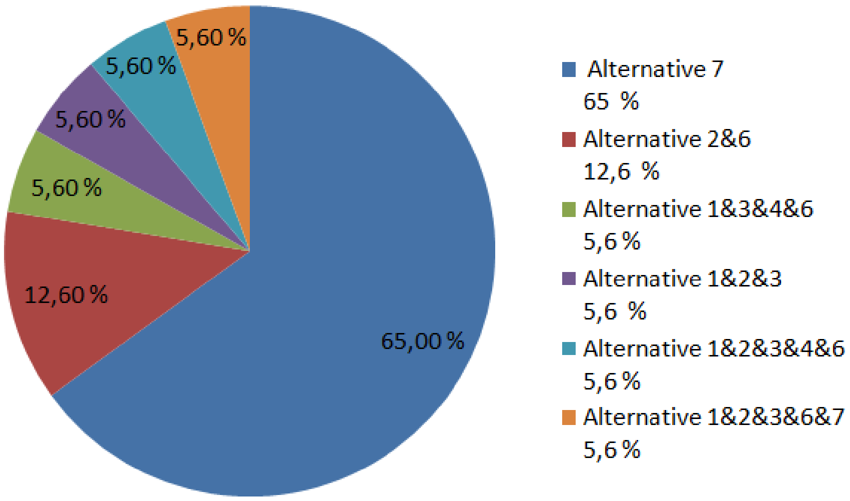


Figure 46: Multidisciplinary design group - Automation answers

The following points are the comments given by the automation engineers who participated in the survey.

1. Operator participation is important as early as possible in order to get a consequent implementation for each system.
2. One participant chose the last option and includes that depends on the project phase. All parties shall contribute, but has to do so on a structured way. In the FEED phase the HMI specialist should own and be responsible for the process. During detail phase the automation/design engineer should own the process.
3. HMI design shall be started before the programming starts.

4. Lack of ISO standardization.

The following diagram (figure 47) shows the response to the questions by HF engineers/specialists.

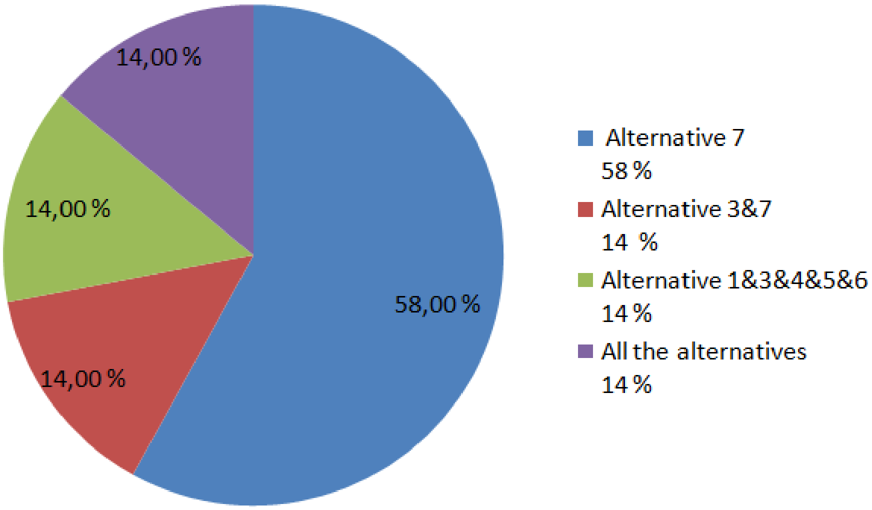


Figure 47: Multidisciplinary design group - HF answers

Attached comments are given by the HF engineers for the question for this chapter:

1. Graphic designer shall be part of the group also.
2. Information architect should be included.
3. *"The design must be multidisciplinary and strongly suggest involving a professional interaction designer".*

<u>Discussion:</u>

Both two participant groups chose the last alternative as their response to this question.

In my point of view HF, automation (designer and programmer) and end-users shall be the main group because based on the case study if one of them wasn't included, the final product could be very different. HF roll was very effective in the case study regarding to lead the process in the correct way and give input about the HF criteria's which was necessary in each part. Automation had the main roll regarding presentation of information in a correct way and end-user involvement early in the design made it possible that the pictures took care of adjusting the HMI based on the operator task. And other engineering groups were involved when it was needed. As one of the comments mentioned above was the lack of ISO standardization. I totally agree on that and based on my experience and research through this report the HMI design process now is based on the different clients' culture of HMI design and not based on what is the best for the operators/end-users.

11.2.5 Automation knowledge about HF

Regarding HMI design, what an automation engineer shall have general knowledge about your work? (More than one option can be chosen)

Alt.1 General knowledge about Human Factors Engineering
Alt.2 General understanding about Task Analyses regarding HMI
Alt.3 General understanding of the Human Factors responsibility regarding HMI design
Alt.4 To be aware about using ISO-11064-5actively during the HMI design process
Alt.5 All mentioned above
Alt.5 others, please explain

This question was included because during the case study I notice that if the automation engineers involved in the case study didn't have enough understanding of the HF responsibility and work for the HMI design it could lead to much longer design process which means more cost for the project and weaker product regarding operator task.

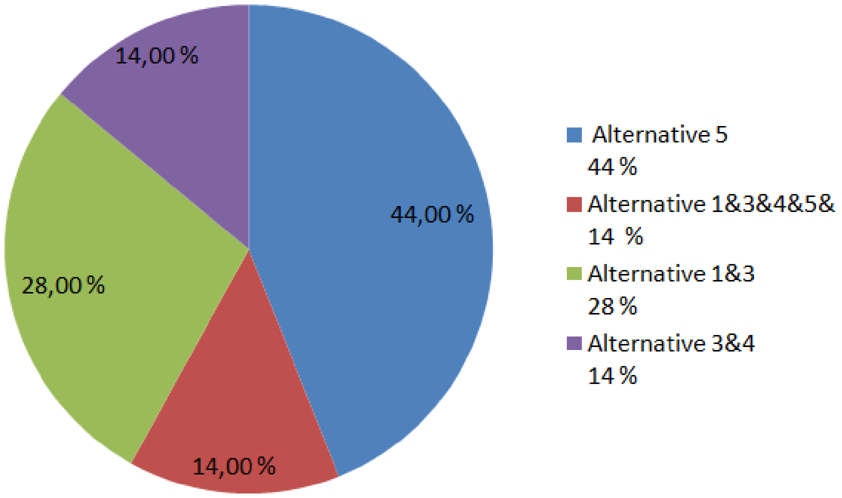


Figure 48: Automation knowledge about HF

Following comments is given by the HF to this question.

1. Advantage to be familiar with ISO 11064 part 1 and part 7.
2. One mentions that the question has not been clear. Also the participant includes that *"this is applicable if automation engineer is taking part in the HMI design then the automation engineer must know that successful design must be based on a multidisciplinary design team".*

Discussion:

As the answers show automation engineers shall have some knowledge about HF responsibility and work. In the case study the HF specialist had several workshops for the engineers involved in the HMI design process to give them enough understanding and information about the HF responsibility and the criteria's which was important to be aware of by the automation engineers. But in my point of view it shall be more research regarding this question to find out how HMI product is affected if the automation engineers involved in the design process don't have any HF engineering knowledge.

11.2.6 HF knowledge about Automation engineering

Regarding HMI design, what a Human Factors engineer shall have general knowledge about your work? (More than one option can be chosen)

Alt.1 Total understanding of System Manual (How the process system is designed and works)
Alt.2 General understanding of System Control Diagrams
Alt.3 General understanding of Process and Instrument Diagrams (P&ID) or Process Flow Diagrams (PFD)
Alt.4 General Knowledge about the normative standards used in Control system design in Oil and Gas Industry
Alt.5 All mentioned above
Alt.6 Other, please explain

This question was included because during the case study I notices that if the HF specialist involved in the case study didn't have enough understanding of engineering documents it could lead to much longer design process which means more cost for the project and also HF couldn't be able to give correct input to the design. It has to be mentioned here that the HF responsible in this project from engineering company had 10 years experience in HMI design in the oil and gas industry and he had a good understanding of the engineering document. Figure 49 shows the answer given by automation engineers.

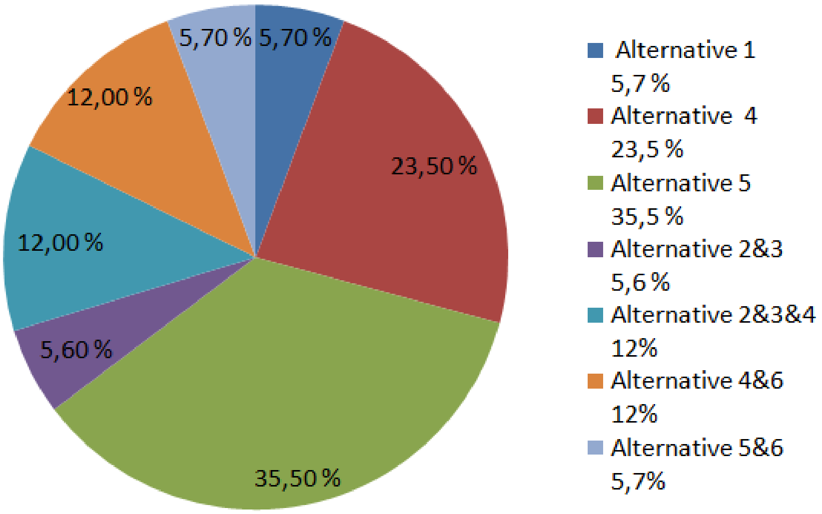


Figure 49: HF knowledge about Automation

Following points are the comments by automation engineers for the question:

1. HF should have a good system to control the process and the operator's strength and limitations. HF should know what solution is the best for achieving a good interaction between the human and the machine (HMI).
2. HF shall have the general understanding of how the system is designed and works. HF responsible will only facilitate and lead the process.
3. HF shall have detail information about the system that his/her has the responsibility for, not necessarily for all the systems.

4. Since the design of the HMI pictures is related to the SCD's and how the main process is designed and works, it is crucial that the HF have general understanding of the SCD's. Otherwise he/she won't be equal in discussions and will make no useful input.

Discussion:

Based on the answers from automation engineers to this question the lack of standardization is clear regarding the background and knowledge which an HF responsible shall have for being able to lead a HMI design process. As mentioned before if the HF responsible who was the leader of the HMI design process didn't have the understanding of the plant and the engineering documents the process could take much longer and he couldn't be able to give correct input during the design.

12 DISCUSSION

The main goal for the thesis from the start has been to explore how the following points are achieved during the HMI design process:

- Ensure that different systems supports the end-user
- Ensure end-user involvement in a systematic and effective way
- Find out about the normative and informative standards regarding HMI design
- To map challenges and result of a HMI design process for an onshore plant to see if end-user involvement from the start can help a better design and also to map the teamwork between HF and automation and other engineers involved in the process.

To specify and structure the work eight research questions were made at the start of this report (Ref. part 1.1). In this chapter the answer to the questions based on the literature review, case study and the email survey is included under each question to prove that how the designers can ensure the goals mentioned above are achieved during the HMI design process.

1. How can the designers ensure that the operator has a permanent overview of the current status of the system they are responsible for (Based on original question in [7], 2008)?

Based on the literature reviews and the case study, it is not possible to give a general answer to this question. Based on the articles presented in chapter 4.5.1[6] and chapter 4.6 [12] the LSD can help the operators to have a permanent overview of the current status of their system. Or based on TR 1212 [18] presented in chapter 6 the overview pictures "Level 2" can help the operator to have all necessary information from each system in one single picture. By using the multidisciplinary HMI design process in the case study overview HMI's was included (called level 2 in the case study) for the process system if it was needed based on the operator task. Also the most important overview was included in the LSD. But the most important point which can help a good HMI design regarding overview pictures is an active involvement of the different engineers who has designed the system and also to involve the end-user from the start of the design process for overview pictures. To ensure the best design regarding overview pictures the use of brain storming method is very affective. The first step can be started by clarifying the concept and goal for each overview picture to evaluate which system dose need an overview picture regarding the complexity and operator task.

HF role [2] is very important for this part of the design process, also the facilitator during the HMI design development shall be a person who can lead the meetings to correct direction. There are four main rules regarding to use the brainstorming method [16], they are:

- Critics is not aloud during brain storming
- Welcome wild ideas
- The more ideas the better
- Combine and improve the ideas

These for rules maybe sound very easy to follow but as I have experienced each of us wants to deliver the best product and the best design and it makes it difficult to let other ideas be noted. In this matter the role of HF is very important first to lead the meetings to the correct direction and also to ensure that these four rules are followed and also to ensure that the human factors criteria's are correctly followed.
There are different brainstorming tools which can be used during the multidisciplinary design meetings but it is not included in this report.

These design meetings can be planned very affectively by involving the automation engineers from the first step. Because the automation engineer who has designed the SCD's can explain many different cases regarding different process scenarios, PSD and ESD for the system and explain the operator task regarding each system. Without involvement of the automation engineer , the engineers responsible for this activity should use lots of time to read and learn every detail about system to be able to go through evaluation of dose system need an overview picture or not?

The evaluation of including overview picture shall be started at the start of the HMI design process to ensure that the operator has a permanent overview of their system if it is needed regarding the operator task and the complexity of the system.

2. How can the designers ensure that the required exchange of information during shift changes minimized by the system (Based on original question in Ref. [7], 2008)?

One of the goals of the LSD basic concept design in the case study included in chapter 10 was to give most important information to operator at a glance. This helped minimizing exchange of information for next operator at shift change because the main process overview picture helped the operator to have a total overview of the main system and all the interface plants connected to the main system. The need of including this part to the concept design of the LSD in the case study was that the main information about manning in the control room was given and the multidisciplinary design team was able to evaluate early in the design that this overview part in the LSD can help the operators at any time.

In chapter 4.5 and 4.6 different concepts for LSD design is included. But the following cases shall be clarified before the start of design process for LSD's:

- Manning plan in the control room is clarified
- Basic concept about the size of control room
- Clarify how many screens is going to be used in control room or it is needed
- Basic deviation concept about PCS,PSD,ESD and CCTV pictures in the control room
- Involving the end-user from the start of process

In the case study the design team had all information needed from the start of design process.
The quality of the design is going to be affected if the cases mentioned above are not clarified at the start of design process.

3. How can the designers ensure that the requirements of all potential users (e.g. maintenance) been considered (Based on original question in Ref. [7], 2008)?

In some HMI-sketches in the case study it was included graphic for manual valves which usually are not shown in the graphic which give better communication ability to the operators in the control room and the operators in the plant. For these cases based on end-user suggestion and process and control information the valves graphic was included. Also special HMI-Sketch was developed for start and stop sequences. Normally the sequences are shown in form of a "faceplate". But regarding complexity and better overview this sketches were included for all the sequences. If in the case study the multidisciplinary design process weren't used the final product didn't include any manual valves or special made sequence pictures for the operator.
These improvements show the affect of a good and affective HMI design process which has been able to include the requirements for all potential users for different systems.

4. How can the designers ensure that all the information presented are relevant to the task (Based on original question in (Ref. [7], 2008)?

By the check list used in the design process included in chapter 8, each HMI design review meetings started with use of “walk through” method. The system task and operator task for each system was presented by the automation engineer responsible for the SCD design. The check list was an effective tool regarding to map the operator task in detail. In this case it was very important that the HF specialists had a general understanding of the process systems otherwise HF specialists cannot be affective and give correct input during this part of the design process.

Based on the result from the email-survey part 11.2.5 and 11.2.6, the lack of standardization for the qualification of the automation and HF personal is clear. Both groups suggest different answers about which knowledge the other part shall have. These shows each of participant have experienced that not having enough information and understanding of each other’s work and specialty can lead to fail of the HMI design process.

To ensure that HMI product includes the information needed for operator task this teamwork is much more important than the other parts. Because the HF task analysis is part of the HF responsibility but automation have all the information regarding operator task. A good teamwork between these two groups can be very helpful to give a correct picture of the system to the end-user and can help the end-user to be more affectively involved in the design process regarding HMI design based on operator task.

5. How can the designers ensure that all the information required to complete a particular task has been presented on a minimum number of displays (Based on original question in Ref. [7], 2008)?

Based on the case study the involvement of the end-user early in the design was very affective for this question. One of the cases was for a system which is not included in the case study, 3 HMI sketches was reduced to one sketch during the design process. Suggestion of including all 3 sketches in one first was given by the end-users involved. When the final sketch based on their comments was developed every member of the design group was agreed that it was the best solution for this particular system.

Another affective tool to be able to minimize number of displays was the affective and multidisciplinary design process development. The total assumed amount of the HMI‘s were reduced by 15% at the end of step 5 of the design development process, which means less displays and better overview for the operator. This can affect the operator roll in critical situations and improve safety by using less time to make a decision in the control room.

There is no guaranties the 15% reduce of HMI is an achievement for all other projects by using this method. But it shows how effective this design process has been for this case study so far.

6. Why is the LSD used in the control rooms and how can the LSD help the operator?

Large screen displays are typically designed to support shared situation awareness in the main control room [6]. In chapter 4.5.1 different concepts for the design of LSD is discussed.

In the case study as mentioned before, the basic concept and goals was defined before choose of the technology. To have a clear understanding of the complexity of the plant and information about how many operator are going to work in the control room are the most important factors for deciding to use an LSD in CR or not.

In this case when the basic manning plan was one operator in CR, the overview for F&G and main process was accepted by the end-user regarding to give control to the operator at any time. But if the design group did not had any complete overview of the complexity or if the normal manning plan were not defined or if the end-users opinions were not taken to account how the size and the technology for LSD can be decided?

There are no standards regarding LSD design but based on the literature review and the case study it is very important to define a clear concept for the control of the plant at the start of each project. If for example the manning plans of a control room are normally one operator or normally three operators the HMI design concept can be very different from each other.

By defining a clear concept early in the design the correct size and correct technology can be chosen for the LSD. But by making decision about the size of control room and LSD before having a clear concept and goal can lead to fail and redesign. How can end-user give input to a good LSD design when the size and the technology for LSD screens are already chosen before the end-user can have any effect of what is useful for end-user?

7. How can the HMI design process be described from the Process Flow Diagrams to the final human machine interface? (With main attention of process information requirements)

The design process for the case study was based on the TR 1212 and Guide line 1212[18] delivered from the client in the project. The TR presented a solution for graphics and software functions presentations in detail. But the design process was described in 10 steps and very general. The design process described in case study it is an adapted version of the process described in the technical requirements from the client for this project.

Figure 50 below describes the traditional way of the HMI design process.

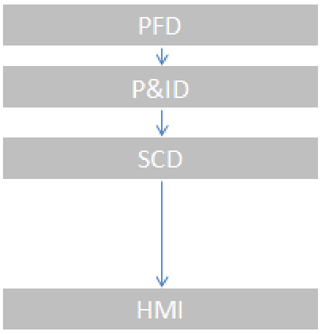


Figure 50: the traditional HMI design process

But the design process for the case study has been totally different shown in figure 51 and has been presented in chapter 6.4.

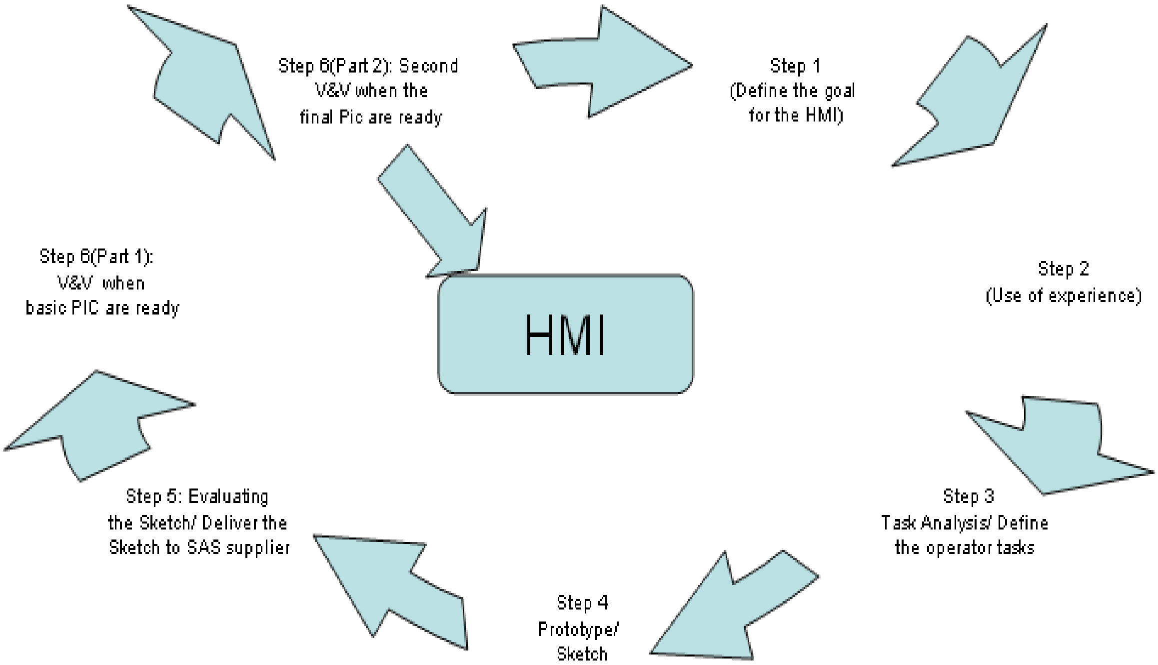


Figure 51: HMI Design Process

As it is presented in the case study the HMI improvements has been a lot during the HMI design process. Use of simple evaluation method “prototyping” of the HMI by just black and white drawings has been very effective tool. The method is cheap to use comparing to change of the HMI product when all programming activities are finished.

A detail description about a multidisciplinary design process is presented and discussed in chapter 5, 6, 7, 8, 9 and 10. Based on the literature review and the case study and email-survey result the correct design process shall be done by a multidisciplinary group including end-user. The HF discipline shall be responsible to facilitate the group and have a close teamwork with automation designer as much as teamwork with the end-user. The information presented in chapter 7 is included to give a summary of all the information which an automation engineer takes to account when designing the SCD’s. The automation engineer’s main role in the design process is to ensure that all necessary information is highlighted and used in the correct place in the HMI by developing the sketch concept or use of other type of evaluation and design tools. The HF roll is to facilitate and lead the process to correct direction and also give input about HF criteria’s which shall be included in the design. The end-user involvement early in the design is very affective. But it has to be mentioned here that both HF responsible for the design process, all automation engineers involved in the design, SAS supplier representative and the end-users were very active during design process. Being active means that each of the group members had read about the system which was the topic of the meeting. If the design group are not prepared before the meetings it can lead to ineffective design process by not being able to give correct input and by using more than time than it‘s necessary. And this can lead to more cost for the project.

8. How can the teamwork between HF, automation, end-user and other engineering groups affect the HMI design process more positive?

Based on my experience, the check list made by HF for the sketches presents the last step of the task analysis. In my opinion it should be an engineering document called HMI user task analysis, where the check list is included for each system or each HMI if it is needed (for special cases). The HF and automation (SCD) designers shall be responsible for HMI user task analysis. In my point of view none of the disciplines can perform this analysis alone. Because the knowledge each of us has about the system shall complete the other disciplines information and experience regarding HMI design and with input from end-user the final product can have high quality regarding operator task and safety.

Some examples about why automation and HF have to work together during the design process are:

- Automation has knowledge about the performance of the system, and HF has knowledge about how it should be presented.
- Automation has knowledge about the technical text description and HF can complete the correct use of the words regarding the whole system and not just one of the HMI's.

In this case study the HMI philosophy was a result of co-operation between HF and automation. The HMI sketches were signed by both the automation and HF.
But what is important for this teamwork was that the HF responsible for HF engineering and design had enough/general understanding and knowledge about most of the engineering documents which was used.

For example when HF and automation had the first meeting for start of a concept, the engineering documents or information needed for HMI was introduced in 10/15 minutes. When the HF responsible understands the basics of the engineering document it makes the design process much easier and more effective.

HF responsible had workshop for automation engineers involved in the sketch design to represent HF responsibility and highlighted the cases which was important for HMI design.

The SAS supplier representative was very helpful during the reviews to evaluate the possibility of some software solutions which was discussed in the meetings. Also the SAS supplier role was very important to make a HMI-sketch element library which reflects the final graphic elements as much as possible.

In my point of view the good co-operation between all the automation engineers and HF was a key for a better HMI design process. And being agree and understand the importance of the end-user opinions was the key to success so far in the project.

Also involving the other relevant disciplines helped to correct the information needed for the HMI. For example involving technical safety engineer helped to give better HMI for LSD safety zones and the F&G HMI as well, or involving process engineers regarding the detail information for special process scenarios has been very effective. The most important reason to conclude that the design process in the case study so far has been successful is that the end-users involve have been satisfied with the result of the design process so far based on my impression from the meetings.

12.1 New approach

To my best knowledge the concept of linking PFD's to HMI basic concept design development process through the SCD's has not been addressed in the previous works. In my point of view the design process for the process pictures can be performed more effectively for design of HMI regarding operator task based process pictures. The idea is a parallel work activity between HF and automation from the FEED engineering phase. The scope and methods for HMI design process can be developed by HF and automation during the end of FEED engineering. The development process can give a total description of the **development process** regarding **information requirements**. This doesn't require SAS software clarifications.

In the detail engineering the total PFD of the plant can be used as a basic scope of the start of detail HMI design process. A total PFD of the plant usually includes all the main process systems in one single document. Process discipline develops usually PFD's for each process system based on the main PFD. These deviations can be used by automation engineers to use the same deviation for the design of SCD's as much as possible. If the HMI development process responsible just follows the hierarchical deviation links from the main PFD to the main SCD and follows this link to the SCD for mechanical package and sequences, then the basic of navigation hierarchy system is designed through the work. This can make the work for the **basic scope design** for each picture much easier and traceable. By correct deviation of the SCD's as much as possible regarding HMI process the work for evaluating information requirements for each picture is more systematic and all detail information needed for evaluation is clarified. By following this deviation philosophy and involving HF through the work, before the start of detail HMI design some part of the **basic scope** is clarified, and in my point of view this make it much easier for the end-users to understand the system and help them to evaluate what they need to add or remove to perform the operator task. The basic concept of this idea is shown in figure 52 as an example for one system named "system 1". This concept can be a link between NORSOK I-005 and the ISO 11064-5.

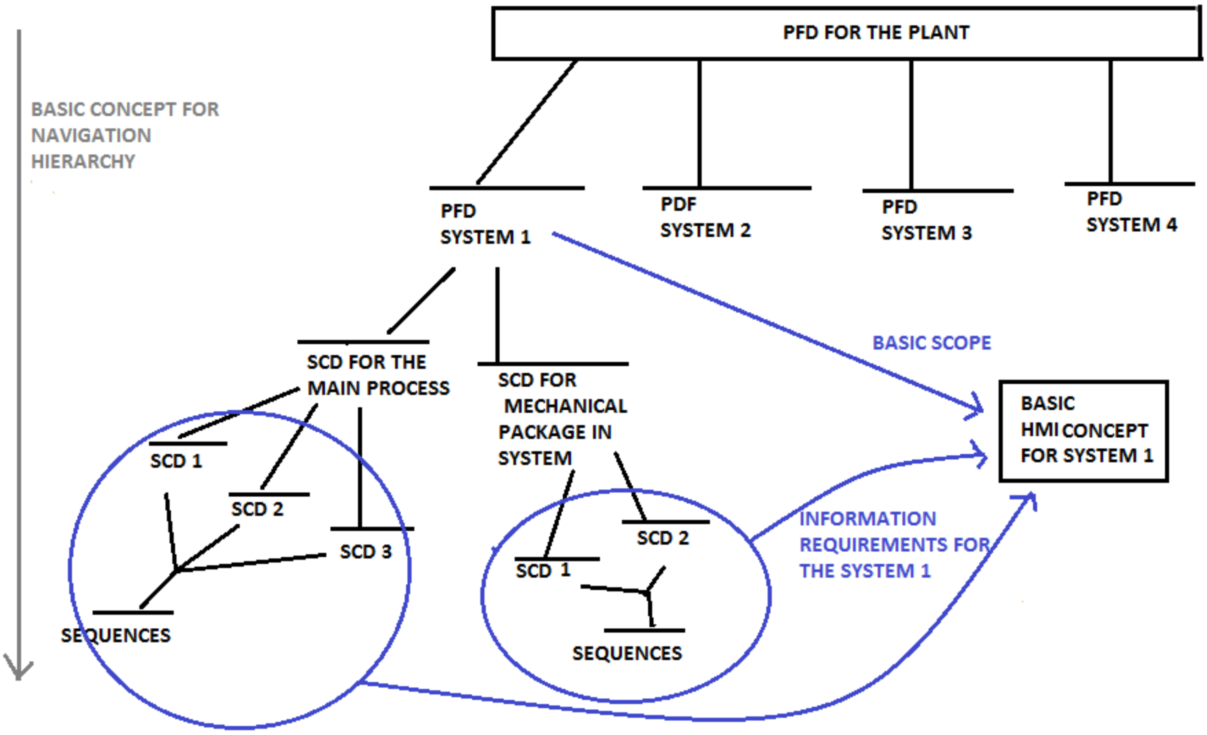


Figure 52: Possible direct link between NORSOK I-005 and ISO 11064-5

13 CONCLUSION AND SUGGESTION FOR FUTURE WORK

In general, based on the literature reviews, case study and the result of email-survey a good teamwork between automation engineer, HF and end-user is main key to design a better HMI. Having enough knowledge about the other responsibility and work between HF and automation is the key for an effective design process regarding the final product quality, time and cost of the HMI design development process.

HF shall have the responsibility regarding the graphic, ergonomic design and all HF criteria which is their responsibility and specialty through the design. But as mentioned in the report HF and automation shall have a close teamwork to be able to ensure that the information requirements mentioned in the ISO 11064 part 5 is included in the design.

Other engineering group's involvement in the case study has shown that all relevant engineers who can contribute to a better HMI design shall be part of the group when it is needed, such as technical safety, electrical or telecom engineers.

There is no doubt about involving end-user from the start of the HMI design process. No matter how much other members of the design group try to design the pictures based on the operator task but based on my experience there are always some points which could be better presented and included in HMI based on the input from end-users. But there are different practices about the role definition of end-user during the HMI design process.

For design of a control room for a new plant the method used in case study can be suggested. The key words of the successes is multidiscipline knowledge about the others work and role, active members who are prepared before the meeting and to focus on the main goal which is to contribute to design the best HMI based on the operator tasks.

Based on this work, PFD's, P&ID's and SCD's are very useful during the HMI design process, but in the case study is described that the HMI sketches was a prototyping tool for this project and having a better SCD helped the designers to design a better HMI sketch but SCD's alone is not enough to be used directly for the HMI design. The idea of a more structured HMI development process presented in chapter 12.1 might contribute to find out how effectively different engineering documents can be designed and used regarding HMI development process. But further research in that matter is needed.

The validation and verification activities are very important for the HMI design. As mentioned earlier the check list made and used by HF responsible can help to map the challenges for each system regarding operator task. Also a scenario based user test can be very helpful as the last step of the design to find out that all information requirements needed for each system is included in the design. But there is a lack of standardization or an international guide line which can describe the best methods for an affective scenario based user test.

There is also needed more research to clarify when the HMI process shall start during detail engineering. There are different practices and methods used in different projects. In this case study the development of the HMI-sketches were started when the last version of SCD's were almost completed. Base on the case study experience the HMI detail design development can be started when Ca. 70% of the information needed for SCD's is clarified.

In my point of view the design process described in the case study has been very affective development process with the focus on the end-user and end-user task. But there is needed more research about how this design can be done for integrated operations, when for example there is one plant which can be controlled by the operators from onshore or offshore.

Also another case which would be interesting to find out is to map the economical affects of this design process. To map if all those improvements which have been included in the design during HMI-sketch reviews (before start of the programming) would have been done after programming, what was the economical consequences comparing with the cost for this design process.

Those who have participated in HAZOP studies for different projects know how carefully these studies are presented. The affect of these studies are proven to all who participates in this kind of study. In my point of view the multidisciplinary HMI design meetings shall be given the same attention as HAZOP meetings. Because in critical situation the system representation in control room is the first tool that can help the operator to a correct decision making in a short time. By not being careful about the design process or by not involving the relevant engineers or specialists or end-user in the design, the designers help the end-users to fail in critical situation rather than success in operator task performance.

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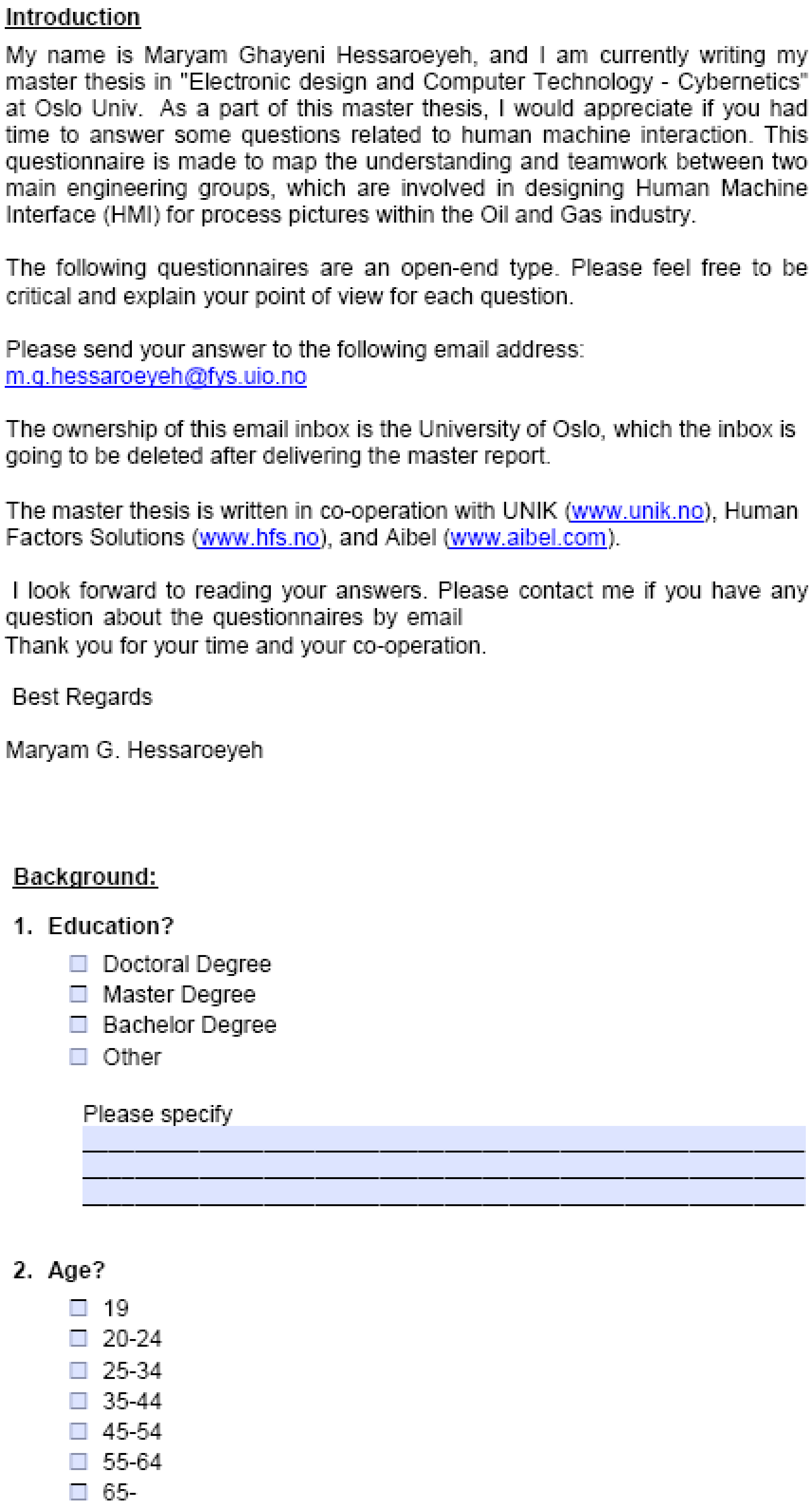
General presentation of the documents references used during the design of different parts in the case study:

- Relevant P&ID’d for the Flue Gas system and LSD main process overview
- Emergency Shut-down Hierarchy
- Process Shut-down Hierarchy
- PFD’s relevant for the Flue Gas system

- Safety and Automation Philosophy
- Reuse Solutions, Software library(SAS supplier engineering documents)
- HF Task Analysis
- HF checklists relevant for the Flue Gas system and LSD
- Instrumented Protective Functions Description and Control Narrative
- Process System Manual for flue gas system
- System manual for the Blower package(supplier document)
- TR 1212, GL 1212(client documents)
- SCD’s relevant for the flue gas system
- Action lists from the HMI-sketch design reviews
- Action lists from the HMI-design basic concept development
- HF workshop material
- Safety Philosophy
- HAZOP Repots
- Safety and Automation system-service description
- NORSOK I-005
- ISO 11064-5 and ISO 11064-7
- HMI Design Philosophy

ATTACHMENT A: EMAIL-SURVEY



Introduction

My name is Maryam Ghayeni Hessaroeyeh, and I am currently writing my master thesis in "Electronic design and Computer Technology - Cybernetics" at Oslo Univ. As a part of this master thesis, I would appreciate if you had time to answer some questions related to human machine interaction. This questionnaire is made to map the understanding and teamwork between two main engineering groups, which are involved in designing Human Machine Interface (HMI) for process pictures within the Oil and Gas industry.

The following questionnaires are an open-end type. Please feel free to be critical and explain your point of view for each question.

Please send your answer to the following email address:
m.g.hessaroeyeh@fys.uio.no

The ownership of this email inbox is the University of Oslo, which the inbox is going to be deleted after delivering the master report.

The master thesis is written in co-operation with UNIK (www.unik.no), Human Factors Solutions (www.hfs.no), and Aibel (www.aibel.com).

I look forward to reading your answers. Please contact me if you have any question about the questionnaires by email
Thank you for your time and your co-operation.

Best Regards

Maryam G. Hessaroeyeh

Background:

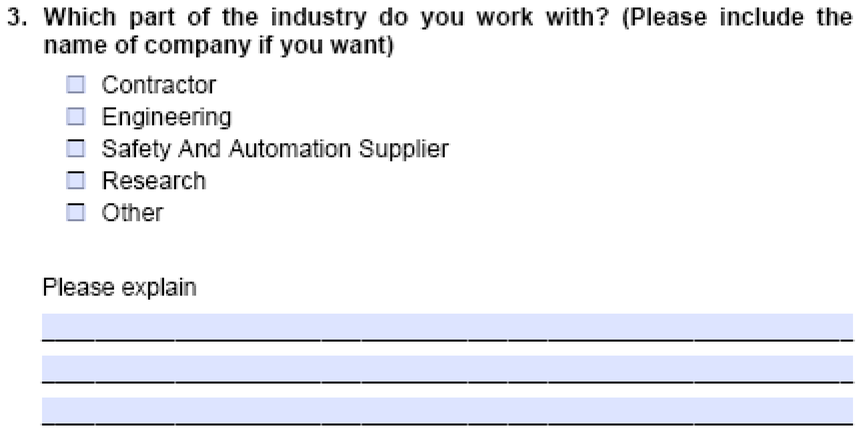
1. Education?

- ☐ Doctoral Degree
- ☐ Master Degree
- ☐ Bachelor Degree
- ☐ Other

Please specify
____
____
____

2. Age?

- ☐ 19
- ☐ 20-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65-



3. Which part of the industry do you work with? (Please include the name of company if you want)

- ☐ Contractor
- ☐ Engineering
- ☐ Safety And Automation Supplier
- ☐ Research
- ☐ Other

Please explain

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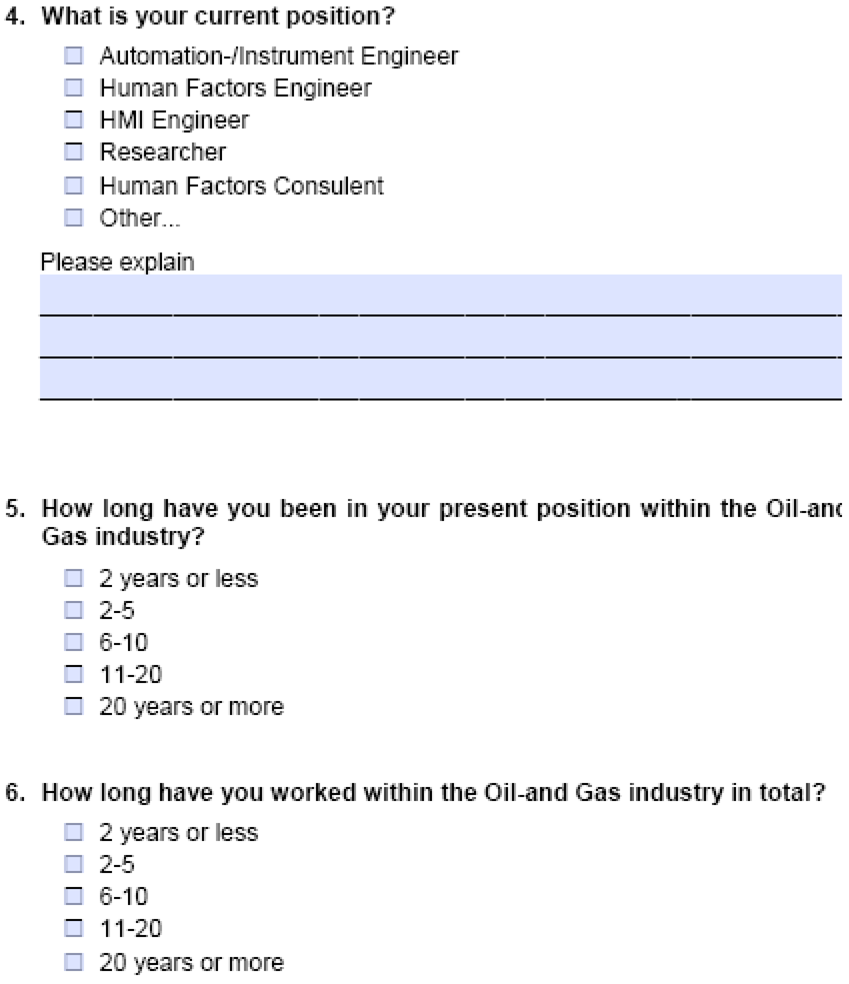


4. What is your current position?

- ☐ Automation-/Instrument Engineer
- ☐ Human Factors Engineer
- ☐ HMI Engineer
- ☐ Researcher
- ☐ Human Factors Consulent
- ☐ Other...

Please explain

____

____

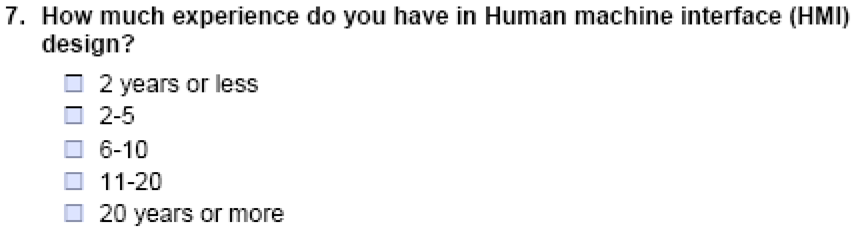
____

5. How long have you been in your present position within the Oil-anc Gas industry?

- ☐ 2 years or less
- ☐ 2-5
- ☐ 6-10
- ☐ 11-20
- ☐ 20 years or more

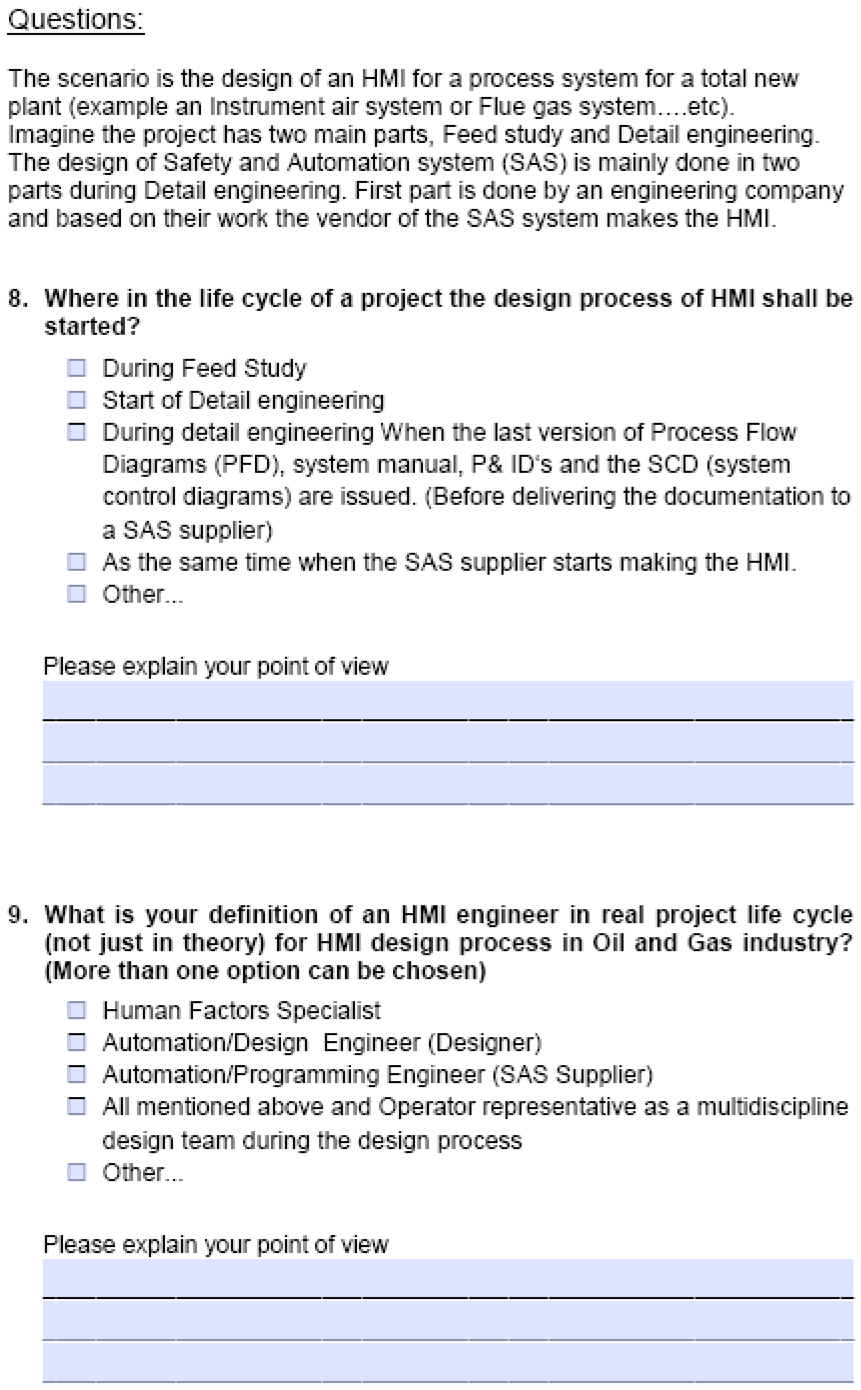
6. How long have you worked within the Oil-and Gas industry in total?

- ☐ 2 years or less
- ☐ 2-5
- ☐ 6-10
- ☐ 11-20
- ☐ 20 years or more



7. How much experience do you have in Human machine interface (HMI) design?

- ☐ 2 years or less
- ☐ 2-5
- ☐ 6-10
- ☐ 11-20
- ☐ 20 years or more



Questions:

The scenario is the design of an HMI for a process system for a total new plant (example an Instrument air system or Flue gas system….etc).
Imagine the project has two main parts, Feed study and Detail engineering.
The design of Safety and Automation system (SAS) is mainly done in two parts during Detail engineering. First part is done by an engineering company and based on their work the vendor of the SAS system makes the HMI.

8. Where in the life cycle of a project the design process of HMI shall be started?

☐ During Feed Study
☐ Start of Detail engineering
☐ During detail engineering When the last version of Process Flow Diagrams (PFD), system manual, P& ID's and the SCD (system control diagrams) are issued. (Before delivering the documentation to a SAS supplier)
☐ As the same time when the SAS supplier starts making the HMI.
☐ Other...

Please explain your point of view
____
____
____

9. What is your definition of an HMI engineer in real project life cycle (not just in theory) for HMI design process in Oil and Gas industry? (More than one option can be chosen)

☐ Human Factors Specialist
☐ Automation/Design Engineer (Designer)
☐ Automation/Programming Engineer (SAS Supplier)
☐ All mentioned above and Operator representative as a multidiscipline design team during the design process
☐ Other...

Please explain your point of view
____
____
____

10. Which of the following choices are correct for at the HMI for process pictures shall be based on? (More than one option can be chosen)

☐ Process Flow Diagrams(PFD)
☐ Process an Instrument Diagrams(P&ID)
☐ System Control Diagrams(SCD)
☐ Mainly based on operator task and also use of all documents mentioned above to get a better understanding of the operator task.
☐ Operator Task
☐ Operator Task and Logic
☐ Others…

Please explain your point of view

____
____
____

11. Who shall be part of a multidisciplinary design group in the HMI design process? (More than one option can be chosen)

☐ Automation/design Engineer
☐ Automation/ Programming engineer
☐ Operator / Operator representative
☐ Process Engineer
☐ Safety Engineer
☐ Human Factors Specialist /Engineer
☐ Human Factors, Automation (design and programming), and Operator are the main design group with help from other groups mentioned above when it is needed.
☐ Other...

Please explain your point of view

____
____
____

12. Answer this question if your specialty is Human Factors.

Regarding HMI design, what an automation engineer shall have general knowledge about your work? (More than one option can be chosen)

☐ General knowledge about Human Factors Engineering
☐ General understanding about Task Analyses regarding HMI
☐ General understanding of the Human Factors responsibility regarding HMI design
☐ To be aware about using ISO-11064-5 actively during the HMI design process
☐ All mentioned above
☐ Others…

Please explain your point of view

____
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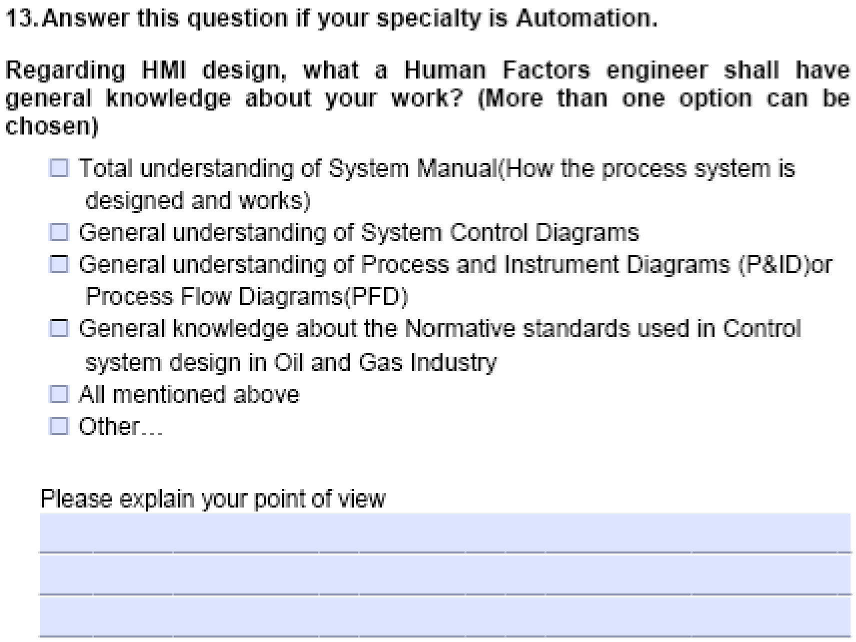

13. Answer this question if your specialty is Automation.

Regarding HMI design, what a Human Factors engineer shall have general knowledge about your work? (More than one option can be chosen)

☐ Total understanding of System Manual(How the process system is designed and works)
☐ General understanding of System Control Diagrams
☐ General understanding of Process and Instrument Diagrams (P&ID)or Process Flow Diagrams(PFD)
☐ General knowledge about the Normative standards used in Control system design in Oil and Gas Industry
☐ All mentioned above
☐ Other…

Please explain your point of view