A Recommendation
for the Future SCADA User Interface for the PWS

The analysis and design of the SCADA visualization and job assistance features for DMT's Pressurized Water Scrubber

Bachelor Thesis
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Summary

DMT Environmental Technology BV. (Joure, the Netherlands) is active in the field of environmental engineering. One of their products is the PWS (Pressurized Water Scrubber) to upgrade biogas. Each PWS plant can be controlled by a SCADA user interface. Currently there is a different user interface for each PWS and users often have a hard time performing their tasks with it. The UI's are very user-unfriendly and give users access to any setting the interface provides. This could result in undesirable errors that have a negative effect on the overall performance of the biogas upgrading process. The current user interface also lacks functionality to improve the ease of and communication between all users.

The report offers a recommendation for redesign of the PWS SCADA user interface. To support this recommendation an example of how the interface *could* be designed has been used. Implementing this redesign recommendation will greatly improve the ease for all users.

One of the new aspects of the redesign is the usage of different user levels to restrict the possibilities of different types of users and to ensure safety. To control the interface it is required that users authenticate themselves. Once authenticated users can control the PWS or change any of the alarm or PID settings. The level of complexity a user has is dependant on the user level of a user. The SCADA system also uses a users username as input for several job assistance features like the data log and the chat and print screen function.

The plants overview page shows all information a user needs to read the PWS process and gives the opportunity to make adjustments to the control settings. The representation is as minimal and as clean as possible. All PWS elements are aligned to a grid and the orientation of the process is presented logically.

The subsystem pages provide full information with all concerning PWS parts and parameters. The build-up of subsystems is consistent to the overview page, keeping all screens as clean as possible to retain comprehensibility.

The redesign stimulates the use of (European) standards. Using standard parts and applying the NEN standard for the colouring of pipelines ensures consistency within the interface and also between the interfaces of all PWS plants DMT offers in the future.

The recommendation improves and implements new features to ease the user and improve their performance. A user does not have to search an entire screen for the exact location of an alarm because the alarm bar offers the option to jump to this location by clicking a single button. The user interface shows the general state of the entire plant as well as the state of individual subsystems to keep the user informed at all times. It is also possible to simulate specific parameters and check their behaviour. Simulated parameters will be presented different from normal process parameters. This report defines all kind of job assistance features to improve the future PWS user interface.

The recommendation will serve as a guideline for DMT and other involving (programming) companies to create a successful user interface for DMT's PWS in the future.

Samenvatting

Dirkse Milieutechnologie BV. In Joure is een bedrijf dat zich onder andere richt op het maken van producten voor het creëren van biogas. Een van deze producten is de complexe PWS (Pressurized Water Scrubber). Elke PWS installatie wordt bediend door middel van een SCADA user interface. Op het moment wordt er voor elke PWS een ander bedieningspaneel gebruikt. Daarnaast is de bediening erg ongebruiksvriendelijk en geeft de gebruiker volledige vrijheid in bediening. Dit heeft als resultaat dat er vaak ongewenste fouten worden gemaakt met een negatief effect op de algehele prestatie van het maken van het biogas.

Daarnaast ontbreekt er functionaliteit om het gebruiksgemak van de gebruiker zowel als de communicatie tussen gebruikers te verhogen.

Dit rapport biedt een aanbeveling voor het herontwerp van de user interface. Dit wordt ondersteund met een uitgebreid voorbeeld van hoe de toekomstige interface ontworpen zou kunnen worden. Het toepassen van de aanbeveling zal het gebruiksgemak voor alle gebruikers sterk verbeteren.

Het herontwerp ondersteunt meerdere user levels om gebruikers te beperken in veiligheid te waarborgen. Om de interface te kunnen bedienen en toegang te krijgen tot de regel instellingen en functies is het vereist om in te loggen. Hoeveel rechten een gebruiker heeft is afhankelijk van het user level van deze gebruiker. Het inloggen is tevens vereist voor enkele toegevoegde functies binnen de interface zoals de print screen functie, chat functie en de data log.

De volledige overzichtsweergave van de installatie is afgestemd op wat gebruikers moeten kunnen aflezen en waar basis gebruikers aanpassingen in kunnen maken. Deze weergave is zo minimaal – zo schoon – mogelijk gehouden. Alle onderdelen zijn uitgelijnd en de oriëntatie van het proces wordt logisch gepresenteerd.

De verschillende subsysteem schermen tonen een volledig overzicht met alle bijbehorende PWS onderdelen en parameter schermen. De opbouw van deze weergave is gelijk aan die van het overzicht. Dit houdt alle schermen zo overzichtelijk mogelijk en zorgt voor een begrijpelijke representatie.

Dit rapport stimuleert het gebruik van standaarden voor het interface ontwerp. Standaard onderdelen zorgen en het toepassen van de NEN norm voor kleurcodering van pijpleidingen zorgen voor consistentie binnen een interface maar ook tussen de interfaces van verschillende installaties.

De aanbeveling verbetert en implementeert nieuwe functies om het de gebruiker gemakkelijker te maken. Een gebruiker hoeft de schermen niet meer af te zoeken naar alarmen aangezien de alarm balk een knop geeft om direct naar de exacte locatie te springen. De interface laat de huidige status van zowel het hele proces als individuele subsystemen zien en geeft de mogelijkheid om parameter instellingen te simuleren. Het rapport beschrijft naast de bovenstaande functies nog meer nieuwe of verbeterde functies om het gebruiksgemak voor alles gebruikers te vergroten.

Dit rapport in combinatie met de gemaakte style sheet dient als richtlijn voor DMT en andere betrokken partijen voor het uitwerken en implementeren van het interface herontwerp.

Preface

Executing this project for Dirkse Milieutechnologie BV has been a great and valuable experience. The people in Joure as well as at the customers in [redacted] in [redacted] were always very kind and willing to help but from time to time were critical as well.

Generally my project went pretty smooth although the first couple of weeks were very chaotic. The underlying process knowledge was missing therefore it took a couple of weeks in order to understand the PWS process. The inclusion of this knowledge was required in order to understand the issues of the current user interface, users and to start tackling this project.

During the project I got confronted with my own planning. At first I planned the analysis phase way shorter. During the first weeks I already noticed this phase always requires more time than expected. Future projects will definitely be planned more realistic and the analysis topics require more preparation in order to decrease some of the time it will take.

Besides planning my own work I have also learned it is important to make appointments well in advance. Everyone at DMT was very busy while I was not full time in Joure whereby it was sometimes hard to plan a meeting.

On a positive note, I am very satisfied with the result I have created. Although there is always room for improvement, I have surely pointed DMT in the right direction in order to greatly improve the future PWS user interface.

I would like to thank everyone who provided me assistance during my project. The following people I would like to thanks in particular:

Jort Langerak, for being my mentor at DMT and guiding me throughout the entire project, providing important information about the PWS and customer experience.

Marten Toxopeus, for being my mentor at the University of Twente, guiding me throughout the entire project and for a cheerful conversation every now and then.

Jolanda Veenstra, for offering her car at any time, so I could travel from Enschede to Joure and visiting customers in [redacted] and [redacted].

Contents

1. Introduction

Dirkse Milieutechnologie BV. is active in the field of environmental engineering. One of the main products DMT offers customers is the Pressurized Water Scrubber (PWS) to upgrade biogas to a high standard. The PWS can be controlled by a SCADA user interface and each PWS has its own way of controlling.

DMT offered the project to write a recommendation for the redesign of the SCADA user interface of the PWS to improve the overall ease for the user.

One of the aspects of this redesign project is the analysis of the interfaces that are currently used and – even more important – the users of these interfaces. Besides this analysis one of the other key aspects is the improvement of current and implementing new job assistance features to ease the user during the execution of their tasks.

One of the most important design principles to support the recommendation for redesign comes from Nielsen (Nielsen & Mack, 1994). Those usability heuristics for user interface design serve as a great guideline in order to create a successful user interface.

During redesign it is also kept in mind that users are very bound to habits. In this case the habits concerning the use of other computer software influence the design decisions made for the redesign. Using those habits in the redesign will make it easier to learn a new interface.

The goal of this project is to write a report that serves as a guide for the redesign of the future SCADA user interface of DMTs PWS. This report will help DMT as well as other involving companies to create a great user interface.

2. Background
This chapter contains background information concerning the company DMT and their products. This will be followed by general information about SCADA systems.

2.1. About DMT
DMT (Dirkse Milieutechnologie BV) was founded in 1987 by Rob Dirkse and is now owned by Erwin Dirkse. The company is located in Joure, a village in the northern Netherlands. Just as every human being, every organization has its mission in life and unique talents no other company has. The organization's talents, skills, background and products determine its Purpose for Existing. The five most important matters DMT Environmental Technology BV (DMT) aims to achieve follow almost naturally from this. These five matters are called the Big Five (for Life). Everything DMT does is connected to the Purpose for Existing and the Big Five (for Life).

Figure 1 – DMT's office in Joure.

DMT's Big Five for Life:
1. DMT aims to clearly distinguish itself from its competitors by continuous development, acquisition and the realization of innovative and sustainable solutions in environmental technology.

2. DMT offers its clients high-grade and sustainable solutions that represent social responsibility and good entrepreneurship with a foundation of professionalism, high quality and integrity.

3. With its products and services, DMT aims to contribute positively to the needs of its clients, thus improving the quality of life on this planet, the success of the company and the interests of its stakeholders.

4. DMT consists of a team of enthusiastic employees who strive to continually improve themselves through work experience and training. DMT offers a challenging and stimulating work environment, especially for Dutch and foreign high achievers.

5. DMT sees co-operation with other organizations and the exchange of knowledge as essential for offering total solutions to the market. These solutions are sold worldwide through a network of agents, distributors and partners.

DMT is a dynamic full service organization that gives clients a central place. Pollution problems are approached with all available knowledge and skills, fully service oriented and with the backup of more than 25 years of experience. Our process engineers and project supervisors are active throughout the world on a daily basis in order to resolve questions together with our clients.

2.2. DMT Services

DMT is active in the field of environmental engineering and contracting. Since the beginning our target has been to realize environmental projects for many applications.

DMT's knowledge and years of experience made the company a professional partner for industries and governmental institutions. Experts analyse the problem and advise the customer which solution is best. Client minded searching for new solutions and possibilities; a clear concept in which DMT combines the search for technical intelligent solutions with an efficient and therefore competitive way of project realization.

Clients are contracting the specialists of DMT environmental Technology for a very wide range of environmental problems. DMT offers the following services:

- Research, development, consultancy and design
- Engineering and Contracting
- Rental of equipment and installations
- Service and maintenance
- Pilot testing
- Equipment and projects
- Pilot research
- Engineering and project realisation
- Replacing of (tower) fills
- Safe disposal of residual substances
- Optimization of purification plants
- Improvements of purification methods
- Airflow and odour measurements

2.3. DMT Products

DMT offers various products for (bio)gas, water or air treatment. The following section provides some background information about biogas and biogas upgrading with the Pressurized Water Scrubber (PWS).

2.3.1. Origin of biogas

Biogas can be produced in different ways. A first option is as a result of landfill, which produces biogas by nature. A second option is collecting biogas by the digestion of biodegradable waste like biomass, manure or organic waste. Biogas created from digestion mostly consists of methane and carbon dioxide but depends on the digested mass. Table 1 shows the composition of biogas.

Substances	Percentage (%)
Methane (CH_4)	55 – 75
Carbon dioxide (CO_2)	25 – 45
Nitrogen (N_2)	0 – 0,3
Hydrogen (H_2)	1 – 5
Hydrogen Sulphide (H_2S)	0,1 – 0,5
Other	Traces

Table 1 – Biogas composition

Because of the high energetic value of methane, it is widely used in the gas industry for the production of heat, electricity or fuel.

The downside of raw biogas is that it contains less methane than natural gas, resulting in a lower energetic value of the gas. Raw biogas also contains a lot of other substances that have a negative effect on the energetic value of the gas.

Cleaning biogas is also called upgrading biogas. The process of upgrading biogas removes harmful substances and lowers the percentage CO_2 in the biogas composition. The quality of biogas is expressed by the Wobbe index. Gasses with equal Wobbe index give an equal energetic value on a specified gas burner.

Upgrading biogas can be realised through different treatments. The first kind treatment involves washing the gas with water or chemicals. Other treatments split different gas substances using membranes or adsorption of carbon dioxide under pressure.

2.3.2. The PWS

Treating biogas with the PWS method does not use any chemicals and supports low implementation- and maintenance costs with respect to other upgrading techniques. The following section describes the general process and different stages of the PWS. An impression of the PWS plant is shown in figure 2.

Figure 2 – PWS Plant from the outside.

Biogas pre-treatment:
In this phase raw biogas is put under pressure up to 8-10 bar as preparation for the second phase.

Water circulation:
After the pre-treatment the pressurized gas enters the scrubber at the bottom of this vessel. Water – entering at the top of the vessel – falls down and washes the gas. During this process carbon dioxide, hydrogen sulphide and a small part of methane are extracted from the gas composition. Washed gas continues to the post-treatment phase. Water will be drained to the flash tank. By lowering the pressure inside the flash vessel, a part of the carbon dioxide and methane will be extracted from the water and transported to back to the pre-treatment phase. After the gas extraction the water will be drained towards the stripper (desorption) where the contaminated water will be regenerated by exposing it to fresh air. The gas flow that arises goes to the

air treatment phase and the regenerated water will be used again to wash raw biogas.

Biogas post-treatment:
The gas flow coming from the scrubber (water circulation phase) will pass a carbon filter to remove small traces of hydrogen sulphide and organic chemicals. After this filter the washed biogas contains a lot of water. To remove the water, the gas is being dried in a gas dryer. After the gas is being dried it will pass a HEPA filter where bacteria and dust will be removed. Thereafter the gas quality will be checked and nitrogen will be injected. The reason for the nitrogen injection is the high percentage of methane in the gas composition. This percentage is higher than the precondition for Gronings gas - the Dutch quality standard for gas. The gas chromatograph checks the final composition of the gas. If the composition of the gas is right the Wobbe index will show a number between 43,46 and 44,41. The final step is the injection of THT (tetrahydrothiophene) that will add the odour of the gas. Naturally the gas is odourless which can cause dangerous situations.

2.4. General SCADA user interface analysis

The PWS plant will be operated by a SCADA system. SCADA is an abbreviation of Supervisory Control and Data Acquisition and is the gathering, forwarding, processing and visualizing of measure and control signals of industrial plants. A SCADA system uses a computer where SCADA software is installed on. This software eases the exchange and visualisation of plant data for human operators. Besides data exchange and visualisation the plant can also be controlled using the user interface the SCADA software provides. Operating the user interface goes with computer mouse and keyboard. A SCADA system can be split in to two parts:

1: Supervisory Control:
This section of the SCADA system provides the visualisation and communication of all processes within the plant and the associated alarms. Data will be presented in a real-time format and is used to intervene the process when required (e.g. whenever an alarm occurs). Controlling the process with the user interface is also part of Supervisory Control. It gives the possibility to change parameters of all programmable logic controllers (PLCs) the plant contains.

2: Data Acquisition:
The second part of the SCADA system gathers, forwards, processes and saves all process data and serves as input for process reports. Those reports will be analysed to optimize and improve the plant.

The SCADA system communicates with the PLC, controllers and other electronics within the plant. The system can read process data, give commands and change parameters whereby a SCADA system regulates itself.

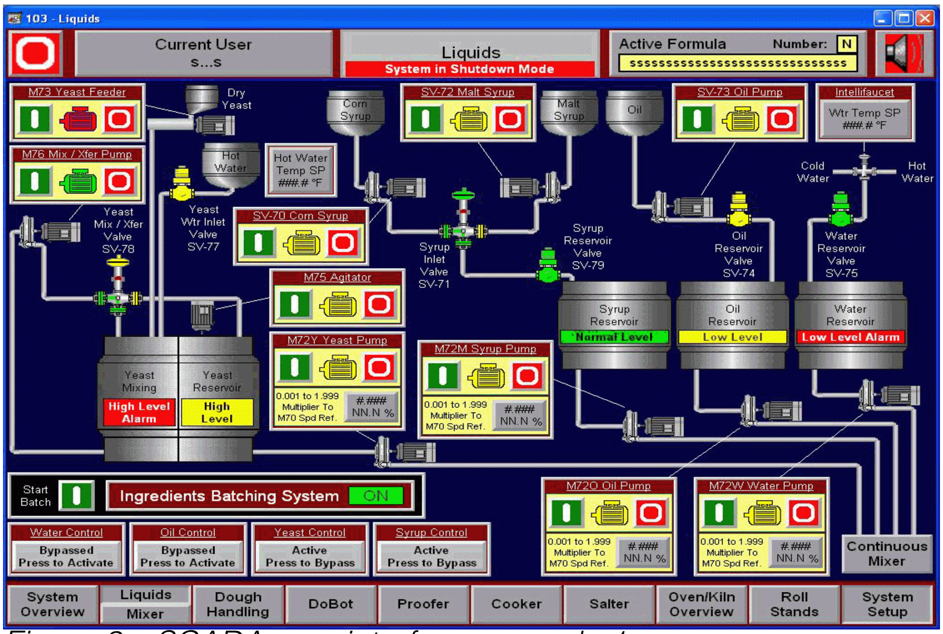


Figure 3 – SCADA user interface example 1.

The plant will be schematically presented on the computer screen using different kind of graphic elements with different functions – creating the user interface of the plant (Fig. 3 & Fig. 4). The plant can be controlled and managed using this user interface. The control philosophy and alarm monitoring is beyond basic user interface level (i.e. on programming level) and determines what can be controlled, when an alarm occurs and many other safeties. Handling protocols, data storage, reporting and communicating are other typical functions a SCADA system can offer.

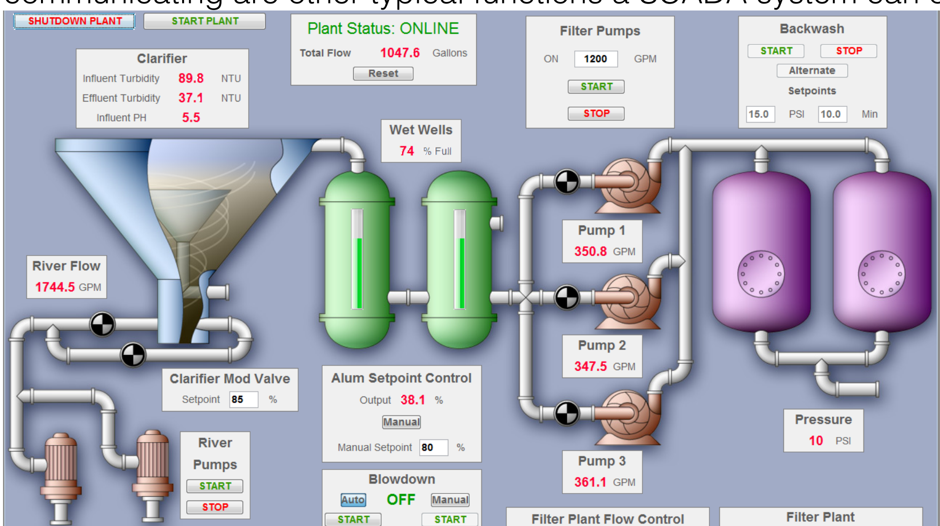


Figure 4 – SCADA user interface example 2.

A SCADA system works with different levels of complexity to which user groups are linked. Each user group has different rights within the SCADA system (user interface).

The SCADA software will be installed on (multiple) server computers dedicated to the plant. Users can gain access to the user interface by using remote connect software and require an internet connection. Whenever there is a problem with the internet or the server computer it is impossible to control the plant.

For more information about SCADA systems, see http://www.tech-faq.com/scada.html

Source figure 3: http://electro-repair-indo.blogspot.nl/2012/12/operator-interface.html
Source figure 4: http://aggregate.tibbo.com/images/aggregate/sh_hmi.png

3. Problem description & research approach

Dirkse Milieutechniek (DMT) in Joure – The Netherlands – is active in the field of environmental engineering and contracting. One of their main products is the Pressurized Water Scrubber (PWS) to upgrade raw biogas to the level of natural biogas.

Renewable energy is becoming increasingly popular and most of all of particularly great importance in the future. The PWS contributes to the generation of green gas that can be used in households, industry and many more applications. Over the years the PWS installation has become increasingly complex. Operators have to be able to manage and analyse large data streams and if necessary intervene in the process by changing certain parameters through a SCADA user interface (control panel). Currently there is no standard user interface that is being used for the installation. The interfaces that are currently used are – especially for operators – too complex.

Every customer has different guidelines and requirements and therefore every user interface is completely different. DMT holds a vision where future PWS installations provide the same user interface – possibly with minimal adjustments because every PWS installation is a little different. The basic user interface functionality and visualization must be the same for every future PWS. Functionality (user interface features) and visualization are two main components the user interface consists of.

The first aspect to this vision is to adapt the visualization of the user interface to the user group. There are different user groups with a wide range of user characteristics. DMT believes that a solid user and usage analysis will provide useful input for the future representation. Optimizing the visualization will increase the productivity, ease the user in their daily work and make the job more satisfying to perform. But more importantly, new or inexperienced users will be motivated, willing to learn and it will decrease the time to learn how to execute their task with the user interface.

The second aspect is implementing useful features that will assist users in executing their task. DMT believes that much more could be accomplished in the way of implementing job assistance features to the user interface. These features would decrease the difficulty of managing and analysing large data streams the PWS contains and clarifies when the user has to intervene in the process. Providing job assistance features will add new functionality and will optimize current functions the SCADA interface has to offer.

DMT thinks a user and usage analysis combined with a concept study for functionality and its visualization will result in a recommendation for the future PWS SCADA user interface. A well considered and argued recommendation for redesign will be the final result of this report and will serve as valuable input for DMT and other companies involved.

4. Analysis phase

In the analysis phase a lot of information concerning the current users, usage and user interface will be gathered. In the end this information will lead to the preparation of the desired features and wishes for the redesign of the PWS user interface. The analysis phase starts off with an analysis of the usage and users of the currently used PWS interfaces followed by the analysis of the current user interface. Findings of both analyses are included in this section.

4.1. Usage Analysis of the current user interface

To get the best possible input about the current user interface multiple interviews have been conducted with both low and high-end users. The purpose of the interview is to find the basic way of work with the interface, difficulties experienced while carrying out their tasks and to discover all thoughts and wishes for task assistance features.

The low-end user group consists of (head) operators at the plant in [redacted] ([redacted]). DMT (service) engineers are part of the high-end user group.

The findings of the interview with low-end users are summarized below.

4.1.1. Low-end user basic task description

An operator's function is to monitor the state of the PWS using the PWS SCADA user interface. This interface shows different kind of information including a schematic representation of the PWS, (important) data and occurring alarms. Besides the current state it is also possible to retrieve data from the past.

When the PWS runs steady an operator just has to monitor user interface in the overview screen. At the start of their shift they write the most important parameters down in a paper archive. Whenever an error occurs it is stated in the alarm bar and it is an operators' task to locate the position of the alarm and research what is wrong. Experience learned that the PWS usually will regulate itself and the alarm will be solved in a short amount of time. If not, an operator has access to all parameter settings and will try to solve the problem by making some changes in one of the PLC settings. Most of the times operators have too little process knowledge to solve the alarms themselves. As a result DMT will be contacted (by phone) to solve the problem.

Every now and then an operator has to start or stop the installation or change the control settings of individual subsystems. To do so they can simply click on the different control options the user interface offers.

Before an operator starts to work with the interface they will get a short course about the biogas upgrading process and a guided course where the basic usability tasks with the interface will be taught. It is important to note that those courses usually are too short and operators have trouble understanding them.

Difficulties experienced:
- Operators have access to all parameters on one hand but too little process knowledge on the other hand. This might result in even more issues while trying to solve an outstanding alarm. Another result could be that the right parameter to change could not be found due to the massive amount of options an operator has.
- Parameters have a specific tag. Operators usually don't know which parameter or part is meant with this tag.

- Operators have a hard time locating the position of the alarm. Although alarm bar does inform the user about the subsystem the alarm is located in, users still have a hard time finding the exact location of the alarm. This is mainly caused by the chaotic representation of the PWS and the minimal visualisation of alarms within a subsystem.
- It is unclear whether the installation runs in steady state in the overview screen. To retrieve this information users are forced to click on one or more subsystems. Those subsystems are even more detailed (and chaotic) and low-end users have a hard time working with it.
- Whenever a parameter is changed the user interface does not log nor visualize the change of a parameter. This way a temporary change could easily be forgotten and might result in another alarm.
- It is not possible to control the PWS in the overview screen or start/stop the plant with one button. Every individual subsystem has to be enabled or disabled in order to start or stop the entire plant.
- In case of emergency there is no way to shut down the plant immediately.

Wishes for task assistance features:
- The user interface should filter the amount accessible data to decrease confusion and prevent even more undesirable errors to occur.
- The operator would like to see a redesign of the schematic representation to make it easier to read the interface and work with it.
- Part and parameter names (tags) should be more understandable.
- Control settings for the entire plant accessible in the overview screen.
- Subsystem control settings accessible in the overview screen.
- Alarms in the alarm bar should help the user with finding the exact location of the alarm in the user interface.
- Instead of writing parameters down in a paper archive it would easy to have a data log implemented within the user interface.
- A quick way to stop the plant in case of emergency.

4.1.2. High-end user basic task description
DMT engineers are the designers of the PWS and have expert process knowledge. Specific names of PID controllers, set points of all different kind of data and the usability of the interface is common knowledge. The engineers might be expert because it is their own field of research, but there are still some problems even they can not find as quick as they want too.

When a new plant is being installed commissioning is required. Engineers will use the SCADA interface to enter and change different data for a couple of days or weeks. Every single parameter has to be accessed manually. Whenever the plant runs in stable state an operator takes over and will start monitoring the plant using the user interface.

During an engineers day at work it is uncommon to check the PWS user interface. The only time they will access the UI is during a service shift or whenever an operator with problems is calling them in. Tasks during the service shift are similar to operator tasks. Engineers will check if the PWS is running the way it should and the state it has been in the past hours. When service and troubleshooting is required more specific interface tasks will be performed e.g. changing parameters or part settings.

Difficulties experienced:
- Every parameter setting has to be entered manually. The commissioning phase will take quiet some time, especially when a lot of small parameter changes have to be done.
- Whenever a parameter is changed the user interface does not log nor visualize the change of a parameter. This way a temporary change could easily be forgotten and might result in another alarm.
- It is not possible to filter the data shown in the alarm history page.
- There is no easy way of communicating data (no export functionality).
- In case of emergency there is no way to shut down the plant immediately.

Wishes for task assistance features:
- The engineer would like to see a redesign of the schematic representation to make it easier to read the interface and work with it.
- DMT engineers would like to include a parameter list where every parameter setting could be changed individually. This would decrease the time required of the commissioning phase and ease their work during service provision.
- A data log where all parameter changes are being saved. Changes made in the past are easily traceable.
- Simulation mode to test single parameters. The user interface should visualize whenever a parameter is simulated.
- User interface should support a way of user authentication. Individuals should each get a certain user level to improve safety and decrease the amount of undesirable errors.
- Include a function to filter the data in the alarm history and other future data representations. Filtering data will decrease the time it will take to find certain information.
- The engineer would like a print screen function to promote communication between operators and/or engineers.
- A quick way to stop the plant in case of emergency
- Chat functionality with in the user interface.

4.1.3. Usage analysis summarized
The conducted interviews gave valuable input for the redesign of the user interface. There is a lot of room for improvement concerning the basic representation and current functionality on one hand and implementing new functionality like data logs, parameter lists and user levels.

4.2. Current PWS SCADA User Interface
None of the current PWS SCADA user interfaces is the same. To get a brief understanding of basic PWS interface elements the SCADA user interface of the PWS in [redacted] ([redacted]) and [redacted] ([redacted]) will be analysed. As with every PWS SCADA interface, actions will be performed with a computer mouse and keyboard. This section will provide a description of the functionality and user interface elements of both the PWS SCADA interfaces. It is important to mention that the user interfaces are not designed by DMT. It is a product of the customer, programming company and DMT.

4.2.1. Overview layout and functionality
The main page of user interface shows a simplified representation of the plant – also known as the overview page. This page shows the most important parts of the PWS and their connections with directional pipelines (Fig. 5 & 6, item A, B). A different colour pipe contains a different matter. Both user interface use different colours for Biogas and Water – the two most common pipes. The table below will clarify this difference.

Matter	[redacted]	[redacted]
Biogas	Yellow	Green
Water	Green	Blue
Air	Blue	Blue
THT	Purple	Purple

Table 2 – Colour difference between [redacted] and [redacted] for different matters.

Both interfaces divide the plant into multiple subsystems. Users can recognize the subsystem division by the partitioning of the planes on the overview page (Fig. 5 & 6, item C). To view one of the subsystems in detail, one can simply click on the desired subsystem plane. More information about the subsystem representation and functionality will follow later this section.

Besides the basic PWS representation the SCADA user interfaces provides a lot of information about the plant and options to control the PWS like a users current location, the alarm bar, parameter frames, alarms and/or warnings, navigation elements and features. The user interface always provides a users current location (Fig 5 & 6, item D).

The alarm bar is used to notify any possible alarm that may occur at any time (Fig 5 & 6, item E). Information communicated by the alarm bar is the amount of active alarms, date and/or time, alarm description and the alarm type. Next to the alarm description there is a button/icon to view the alarm history (Fig 5 & 6, item F).

Figure 5 – Overview page, PWS user interface [redacted].

Important parameter frames shown on the overview page help users to get a good read on the current state of the plant (Fig 5 & 6, item G). Parameter frames are connected to parts or pipes by a thin line. To view more parameters or access their settings users should navigate to the desired subsystem.

Besides the alarm bar the user interface does also show the location of the alarm in the interface by colouring the alarm or warning indication in the bottom right of the associated sub system plane (Fig. 5, item H) or colour the alarming part red (Fig 6, item H).

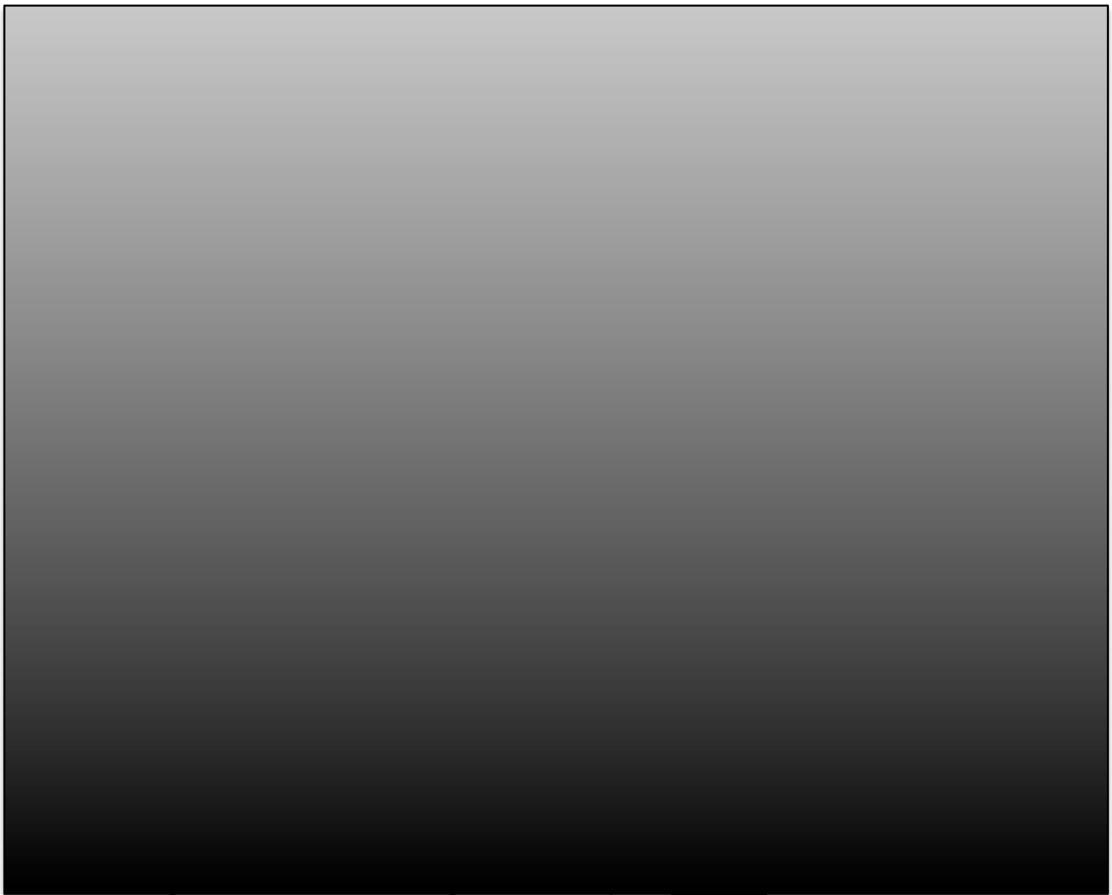


Figure 6 – Overview page, PWS user interface [redacted].

Both user interfaces contain a lot of elements used to navigate through the user interface. In [redacted] (Fig. 5), most options – while in the overview page – are hidden under the menu button (Fig. 5, item I). [redacted] (Fig. 6) on the other hand, always shows every subsystem navigation button regardless the current displayed page (Fig. 6, item I). [redacted] interface shows two extra buttons, one to view the Trend module and the other to reset the alarms (Fig. 5, item J). Way more buttons are shown in the navigation panel of [redacted]. These options give the user the possibility to view trends (Fig. 6, item J), reset alarms, fully start or stop the plant, view process steps and plant releases (Fig. 6, item K) and show or hide extra information and tags (Fig. 6, item L).

Extra functionality and information the [redacted] overview provides is the current user (Fig 6, item M), individual subsystem control (Fig. 6, item N) and the acknowledgement of alarms (Fig 6, item O).

4.2.2. Subsystem layout and functionality

Both [redacted] and [redacted] subsystems give more control options, a realistic part representation and provide the user with more information about the state of the plant. [redacted] interface does not have subsystem control functionality in the overview but provides this function in the subsystem page (Fig. 7, item A). It is also possible to navigate between subsystems by pressing the buttons on the bottom of the screen (Fig. 7, item B). To change a parameter in [redacted], the settings icon next to the parameter frame (Fig. 7, item C) should be pressed. When pressed the parameter settings window will pop up positioned at the position of the mouse pointer. To close the window a user can simply press the cross at the top right of the pop up window. Whenever the state of a valve, motor or compressor could be changed there is a button next to or below this part (Fig. 7, item D). To view additional settings users can click on the valve, motor or compressor resulting in a pop up window similar to the parameter settings pop up. To access a parameters graph, the graph icon inside the parameter frame should be pressed (Fig. 7, item E). A graph window will pop up positioned at the location of the mouse pointer. Pressing the cross button at the top right will close the graph window. It is important to note the pop up windows cannot be moved.

Figure 7 – Water circulation subsystem, PWS user interface [redacted].

To access the settings of any part in Wijster, a part or parameter frame itself should be pressed (Fig. 8, item A) followed by clicking “Options” in the pop-up window (pop up window is not shown in Fig. 8). The pop up window will be located and fully cover the space at the right side of the alarm bar. Clicking options will expand the pop up window to the bottom of the screen. To close the settings a user can press the cross at the top right of the pop up window.

The user interface will notify the user whenever there is an (in)active alarm located in the subsystem. Connected to the parameter frames are circles that will colour red whenever that parameter has an active alarm. When there is no alarm these circles will be green in [redacted] (Fig. 7, item F) or white in [redacted] (Fig. 8, item B).

PWS valves, PID's, motors and compressors show their current state using the same colours as the alarm notification. Green for active and automatic mode (Fig. 7, item G), white for inactive, red whenever something is wrong and yellow for hand mode (Fig. 8, item C). Below these parts there is extra information given like the percentage a certain valve is opened.

Both user interfaces also show dotted lines between parts or parameter frames. This line means that the linked parts or parameters are related to each other (Fig. 7, item H & Fig. 8, item D).

Extra functionality the [redacted] interface provides is the link between subsystems within the subsystem window. Clicking one of the subsystem buttons a pipe leads to will take the user to that subsystem (Fig. 8, item E).

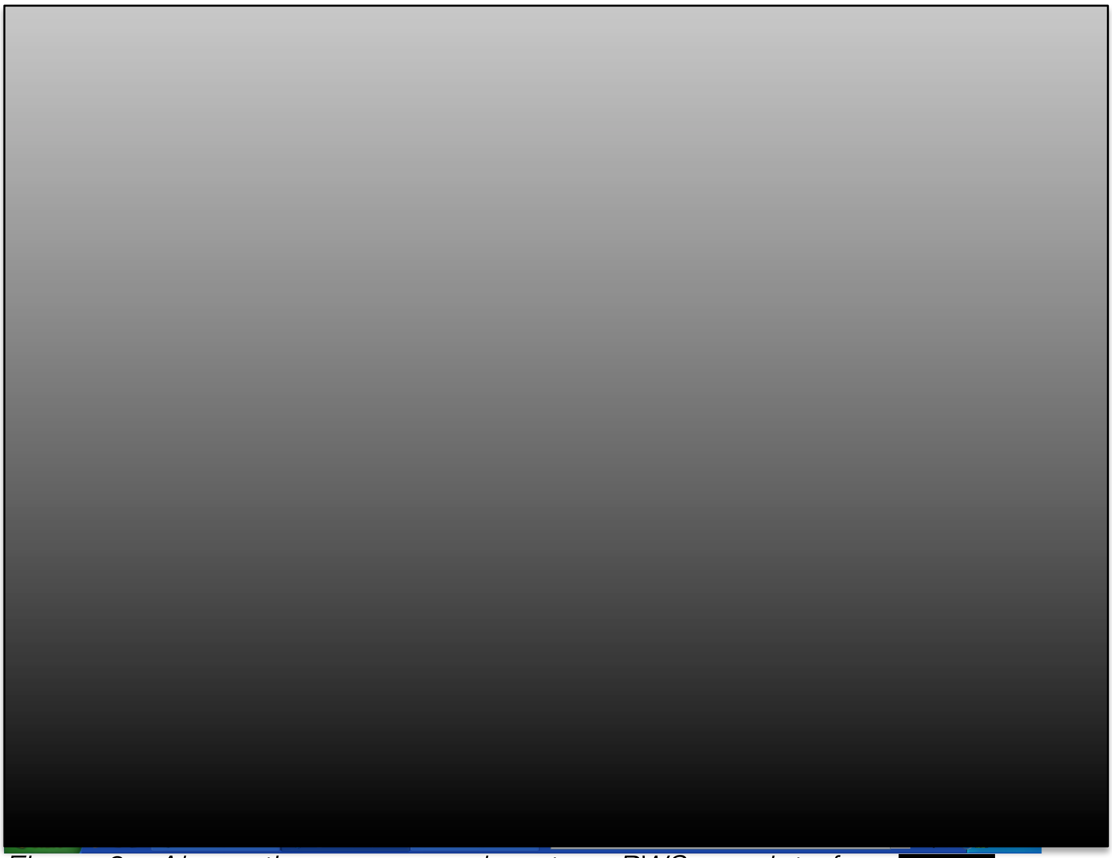


Figure 8 – Absorption process subsystem, PWS user interface [redacted].

4.2.3. Global interface functionality

Alarm history, alarm settings and the trend module are features the interface offers.

The alarm history contains a log of all alarms up to the last server reset. This page is used whenever information about the PWS state in the past is required.

In the alarm settings page users can change the severity of an alarm. Possible options are to make an alarm urgent or a notification.

The trend module shows one or more parameters in a single or multiple graphs. Trends are very important in the current user interface, especially for experienced users. A lot of process information could be derived from the trend module by selecting multiple parameters and view their trend during a certain point in time. This information will help users with alarm management and improve the general process of the PWS.

All of the windows of the functionality stated above will be displayed in full screen mode.

5. Design fundamentals

This chapter contains design fundamentals that serve as solid basis for future design of the SCADA user interface. The design fundamentals are a direct result of the user and usage analysis and the findings of the current user interface analysis. This chapter also contains important guidelines concerning the design of general user interfaces and the design of SCADA user interfaces in specific.

5.1. User profiles

Generalization of the findings of the task analysis and interviews with operators in [redacted] and [redacted] as well as the task analysis interviews with engineers at DMT have led to two user profiles. This profile table (Table 3) serves as guideline for the design of the new user interface.

User characteristics	Operators (new focus group)	Engineers (current focus group)
Age	Range from about 18 to 65 years	Range from about 20 to 65 years
Sex	Mostly male	Male and female
Educational background	Mostly (very) limited educated. UK GCSE's At C level. No experience at all in the field of chemical or process engineering.	Generally University of Professional Education of University of Science. Specialists in chemical, mechanical and process engineering. Educated to design and manage PWS plants.
Physical limitations	Colour blindness. No further physical limitations that might lower the performance of their task.	No physical limitations that might lower the performance of their task.
Experience	Some experience with desktop operating systems or smartphone user interfaces. Unknown with the details or technology behind interfaces. Minimal experience with SCADA interfaces.	Average experience with operating system of smartphone user interfaces. Very experienced in using SCADA interfaces. Using specific knowledge to research and develop current and future plants.
Attitude and motivation	Having trouble to process a large amount of information. Usually bound to habits and find it hard getting used to new technologies that aim to ease their usage with the system.	Will be enthusiastic about change and are willing to learn new things. Engineers find it important that the new technologies are easy to learn but most of all ease them with their work as much as possible.
Routine	Only basic tasks are seasoned. Specific actions are unknown.	High experience could lead to tunnel vision. Commonly used methods could shadow other useful functionality the interface provides.

Table 3 – User profiles.

5.2. Hardware restrictions

The SCADA software will run on a dedicated server belonging to the PWS system. To access the interface operators will log on to this server using remote desktop software. Computers using this software could all have a very different hardware setup but always use mouse and keyboard as input devices. It is important the future user interface is designed for and workable on nearly every computer. Therefore a resolution restriction must be made. The chosen resolution should support both square (4:3) as widescreen (16:9) monitors

The future SCADA interface should be able to run on a smartphone or tablet. Common aspect ratios of smartphones and/or tablets are 3:2 and 16:9. To suit as much of these displays as possible the orientation of the user interface is an important aspect to keep in mind.

Most of the time operators use a desktop computer in the control room of their company. Those computers are not equipped with speakers to notify the user by sound. If the future design contains sound notification it is important users know about this functionality.

Authentication methods of both operators and engineers require an Internet connection. For future design of the SCADA interface more Internet applications could be implemented to improve its versatility.

5.3. Usability heuristics of Nielsen

In interface design it is most important to design an interface for the main user. To reach this goal Jakob Nielsen offers ten heuristics as rules of thumb to work towards when designing an interface (Nielsen & Mack, 1994). Those are often used to investigate and evaluate usability of an existing interface. A new user interface design conform those general principles will most likely be more useable than interfaces that don't.

Nielsen's usability heuristics are as follows:

1. Visibility of system status.
   The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

2. Match between system and the real world.
   The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. User control and freedom.
   Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

4. Consistency and standards.
   Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. Error prevention.
   Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. Recognition rather than recall.
   Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. Flexibility and efficiency of use.
   Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both

inexperienced and experienced users. Allow users to tailor frequent actions.

8. Aesthetic and minimalist design.
   Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. Help users recognize, diagnose, and recover from errors.
   Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. Help and documentation.
    Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

5.4. Specific SCADA interface guidelines

The next guidelines are an addition to Nielsen's usability heuristics for user interface design. The following guidelines are specific for the design of SCADA user interfaces:

1. Use a workable resolution.
   SCADA software often runs on computer systems with basic hardware. Therefore an ideal resolution for a SCADA interface is 1280x720 pixels. Pretty much every device will be able to display the interface without positioning issues.

2. Proper area designation.
   SCADA interfaces often communicate large amount of information to users. To minimize the amount of presented noise a proper area designation is ideal.

3. Use appropriate size UI elements.
   The minimum button size for computer software is 16x16 pixels (Microsoft, n.d.). Active SCADA user interface areas should be at least this size.

4. Use clear colour ratio
   Clear visual difference between different parts of the SCADA user interface improves usability.

5. Present a clear view
   SCADA interfaces often work with pop-up windows, drop down menus or similar forms of screen coverage. Minimization of noise presented on the screen improves usability. Navigation elements and pop-ups may best be placed at the border of the screen or the source of the pop-up.

6. Constrained controls
   Constrained controls like sliders or knobs reduce the amount of input possibilities and with that the amount of actions required.

6. Desired features

With reference to the analysis of the end users and the current interface a list of requirements is made. The requirements are split in two different parts. The first part includes functional requirements to assist users on their jobs. The second part focuses on the requirements for the SCADA user interface. Both lists serve as guidelines for the future design of the SCADA user interface of the PWS.

6.1. Functional requirements

1. The interface should support a way of authentication.
   a. Each group of users will have a different level of interface complexity.
      - The user interface should display the current level of complexity.

   b. Each group of users will have different control rights in the interface.

2. The interface should ease the user by decreasing the difficulty of reading and understanding the current state of the PWS.
   a. The schematic representation of the PWS should be understandable.
      - Schematic representation should only display relevant PWS parts, dependant on the level of complexity and the data the users require to see.
      - Schematic representation should be logically positioned.

   b. The user interface should display the current general state of the PWS.
   c. The user interface should display relevant data.
      - The amount of presented data is dependant of the level of complexity.

   d. The user interface should filter accessible settings of data.
      - The amount of accessible settings is dependant of the level of complexity.

   e. The user interface should filter accessible trending modules.
      - Accessible trending modules are dependant of the level of complexity.

3. The user interface should support job assistance features that decrease the difficulty of controlling the PWS.
   a. Interface navigation elements should speak for themselves.
      - Clickable elements should present themselves as clickable.
      - The user interface should have clear start/stop buttons.
      - Active and/or inactive interface elements should clearly present their current state.

   b. Navigation between different layers of the user interface should require minimal amount of actions.
   c. Changing values should require minimal amount of actions.
   d. Pop-up windows should not obstruct the rest of the interface.
      - The interface should support multiple pop-up windows.
      - Pop-up windows should be moveable or have a fixed position in the interface.

   e. The interface should offer an option to take a snap shot of the current presented view.

4. The interface should improve the PWS uptime by decreasing the amount of critical errors and help users solve occurred errors more efficient in a shorter amount of time.
   a. The user interface should have a clear way of notifying an alarm.
   b. The user interface should state the severity of the alarm.
   c. The user interface should show the amount of outstanding alarms.
   d. The user interface should show the position of the occurring alarm in the schematic representation of the PWS.
      - Alarm notifications should create a link between the notification and the position of this alarm in the schematic representation of the PWS.
   e. Alarms should help the user solving the problem.
      - Alarm notifications should inform the user with important information concerning the alarm.
   f. The system should automatically log changes of data. Corresponding tag, date and time, user who made the change and attached notes will be logged with it.
      - The user interface should present a way to visualize these data logs.
   g. The system should support a simulation modus that could be turned on when a test is being done.
      - The user interface should give the option for simulation mode.
      - The user interface should communicate whether or not simulation mode is active.
   h. The user interface should contain DMT contact information.
      - The user interface should give an option to visualize DMT's contact information for required service.

5. The user interface should match DMT's company image.
   a. Interface representation should match DMT's colour composition.
   b. The interface should contain a DMT logo.

6. The user interface should fit within the stated hardware restrictions.
   a. The user interface should work with mouse and keyboard.
   b. The user interface should be designed conform the stated screen resolution.
   c. The user interface should work on tablet or smartphone.
      - Visualisation of the interface on the computer monitor should also fit tablets and smartphones.
   d. The SCADA system should support job assistance features that could easily import/export data and communicate these over the internet.

7. The user interface should present PWS parts, tags, connections and other elements following understandable (international) standards.
   a. PWS parts should be standardized for future PWS SCADA interfaces.
   b. Tag names, colouring and positioning should be applied in a consistent way.
   c. Line colouring, positioning and direction should be applied in a consistent way.

6.2. SCADA user interface requirements

The user interface design should ease the user conform Nielsen's usability heuristics.

1. The SCADA user interface design should be accessible.
   a. The interface should be operable with a mouse and keyboard.
   b. The interface should be operable on a computer with basic hardware setup.

        - Condition: operational resolution will be 1280x800 pixels.
    c. The interface should be operable on a tablet of smartphone.
    d. The interface should be workable without reflection or dust being an issue.
    e. User interface elements should be visible and understandable.
        - Condition: buttons will be at least 16x16 pixels.
    f. Colour-blind users should be able to work with the user interface without having trouble understanding it.
        - Gray-scale interface elements must have the same effect as coloured elements.
    g. Interface elements should not restrict nor over inform users.

2. Heuristic: Visibility of system status.
    a. The user should be informed which part of the interface is currently displayed.
    b. Schematic representation of the interface should be presented understandable for all users.
    c. The user should at all times be informed about the current state of the system.
    d. The user should be able to retrieve (the most important) data in a blink of an eye.
    e. The user should be informed about unresolved alarms.
    f. User interface should immediately provide the user feedback when navigating with mouse and/or keyboard.

3. Heuristic: Match between the system and the real world.
    a. All users must understand every displayed text and icons.
    b. Schematic representation should match the real PWS.
    c. Tags must be used consistent for both user groups to promote communication.

4. Heuristic: User control and freedom.
    a. The user interface should provide a clear way to undo changes.
    b. The user interface should provide a clear way to navigate through different parts of the interface.
    c. The user interface should provide an easy way to navigate through different menu structures the interface offers.
    d. The user interface should provide a clear way to close windows.

5. Heuristic: Consistency and standards.
    a. Control functions should be used in a consistent way.
    b. Positioning of presented information should be consistent.
    c. User interface design conform understandable colour standards for all users.

6. Heuristic: Error prevention.
    a. Whenever an action results in an error, the interface should inform the user and ask for confirmation.

7. Heuristic: Recognition rather than recall.
    a. Objects, actions and options should be visible.
    b. Hidden options should be displayed by a single modification.
    c. Information should not have to be remembered from one parts of the interface to another.
    d. Usage instructions should be visible or easy to access.

8. Heuristic: Flexibility and efficiency of use.
    a. Frequently used interface options should be visible throughout the entire interface in a consistent way.

9. Heuristic: Aesthetic and minimalist design.
    a. Irrelevant information should not be displayed at all.
    b. Rarely used information will be hidden behind another layer but could be accessed with ease.

10. Heuristic: Help users recognize, diagnose, and recover from errors.
    a. Error messages should be understood by all users and precisely indicate the problem.
    b. Error messages should be able to display the location of the error in the user interface.

7. Conceptual design phase

By means of the large amount and information and prepared desired features a concept design has been made for the future SCADA PWS user interface. The following section will explain this design in general and detail and argue the design decisions that were made.

At first it will be explained how the interface (server) will be approached and how it will be controlled. This will be followed by a brief overview of the parts the interface is built of. All screen displays and functionality will be addressed in detail afterwards. It is important to note that sections 7.1. Connection to the server and 7.2. Controlling the user interface are preconditions for the redesign.

The decisions made will be argued and explained why this will improve the overall ease of the user interface and in what way it will assist a user in their work.

7.1. Connecting to the server

The SCADA system will be installed on a server computer that is dedicated to the PWS installation. Users can connect to this server from any computer around the world. In order to connect to the server a user has to install remote-connect software on their computer. Establishing the connection to the server will require (at least) an IP address and password and an internet connection. The server does allow multiple logins at the same time without users having to share the same screen.

When the connection is successful the user will gain access to the interface. At that moment it is possible to authenticate within the user interface itself to gain more rights to control the PWS. If a user decides not to authenticate, they won't have access to any of the plant settings. By default the user interface will show the user authentication window after the connection to the server is being made. Users will not have to reconnect to change user levels. Clicking the menu button will give the option to "Change User". The remainder of this report will provide further explanation about user authentication and the visualization of this window.

7.2. Controlling the user interface

The user interface will be controlled with a mouse and keyboard. It is also possible to use the touchscreen of a smartphone or tablet to control the interface but this will lower the ease of controlling it. While the conceptual design is mainly focused on mouse/keyboard control, future use of a tablet or smartphone is definitely kept in mind in the positioning of the user interface elements.

7.3. User interface components

The future design will have a fixed frame – one at the top and one at the bottom of the screen – where PWS information and user interface navigation elements are built in. The plant overview or one of the multiple detail screens of subsystems will cover the remaining space of the screen and will be called 'the active area' of the user interface. These different views will give the user insight in the state of the PWS and give access to a wide variety of PWS settings.

The following section will explain every part of the conceptual design in detail and argue why the implemented features and design is chosen.

7.4. Design preparations

Before the development of the interface design it is important to realise that there is a lot of specific information and data the SCADA user interface has to present. The most common data are date, time, sensor and PID tags, descriptions and specific alarm and PID information.

In order to prepare for the redesign the different parameter settings (including settings alarm and PID) require a detailed investigation. The findings will be implemented in the final concept design (see Section 8).

7.4.1. Parameter settings

The SCADA user interface will show the user several parameter frames on each screen. Users will have access to expand the parameter frame showing the parameter settings. This frame will show the alarm and PID settings for this parameter. Whether the user can make changes in this frame is dependant on their user level.

7.4.2. Alarm settings

A parameter can have the following alarm settings (Table 4). The alarm signal the system provides must be visualized by the user interface. By communicating this information a user can intervene in the process to solve the alarm.

Alarm type	Alarm explanation
HH	Higher-high alarm value. When a parameter exceeds this value the system will give an HH-alarm signal.
LL	Lower-low alarm value. When a parameter falls below this value the system will give a LL-alarm signal.
H	High alarm value. When a parameter exceeds this value the system will give an HH-alarm signal.
L	Low alarm value. When a parameter falls below this value the system will give a LL-alarm signal.

Table 4 – Alarm types.

Every alarm type is split in to two different settings. The value for HH_{in} will activate the HH-alarm where the value for HH_{out} will deactivate the alarm again. Some parameters have only got the two HH and H alarm settings. Others have got H_1, H_2, L_1, L_2 in addition to the HH and LL alarm types.

7.4.3. Alarm severity

Every alarm is linked to a level of severity. The different alarm types (HH and H) already give an indication about the severity but not all HH-alarms are the same. When an alarm occurs it will be communicated to the user naming the alarm type and the severity of the alarm. Alarms will be divided in to three different levels:

Severity	Explanation
Urgent (red)	Critical alarm. A user must intervene in the process. If not, the PWS could stop running in the end.
Non-urgent (orange)	Non-critical alarm. Ignoring this alarm could lead to an urgent alarm.
Notification (white)	Alarm without any consequences. A user does not have to intervene in the process.

Table 5 – Alarm severity.

The alarms are split in to urgent and non-urgent alarms because of the difference in consequences they have. The HH alarm type is usually a hard safety alarm. An active HH is therefore (almost) always an urgent alarm. H alarms are less urgent, but most certainly require attention to prevent the alarm from getting urgent. The user interface does provide an option to change the severity of a single alarm. Whether a user can change this setting depends on their user level. More about changing the severity of alarms will follow later this report.

7.4.4. PID settings

Besides the alarm settings the expanded parameter frame will also show the PID settings of a parameter. Possible settings are listed in table 6.

PID setting	Setting explanation
SP	Setpoint value.
P	Proportional value.
I	Integral value.
D	Derivative value.
MAX	Maximum (percentage).
MIN	Minimum (percentage).

Table 6 – PID settings.

A PID controller calculates a value as the difference between a measured process parameter and a desired setpoint. The controller will minimize the difference by adjusting the process control inputs using an algorithm involving the P, I and D. Whenever a user makes a change to one of the alarm or PID settings, it will result in a change of the biogas upgrading process. In the extreme a wrong input could even lead to dangerous situations. Therefore it is important to provide insight in the meaning of the different parameter settings and the consequences changes can cause.

To get this information a list of all parameter of the plant in Wijster (Overijssel, NL) has been submitted to four process engineers at DMT. A small part of this parameter list is shown in figure 6. The bottom of this figure shows the different user level the engineers could choose from. The colour of the parameter setting indicates which user level is required to change this setting. The results of all four engineers are combined and have been discussed within DMT. After adjusting and discussing the levels a few times a final parameter list with the different user level was created.

Instellingen	Setpoints	Biogas	installatie	
	X	X	X	X
Benaming	Gasbuffer niveau	Drukmeting inkomend biogas	Temperatuur inkomend biogas	Temperatuur biogas na booster
Eenheid	%	mbar	°C	°C
Parameter \ TAG	EKG10CL001	EKG11CP001	EKG11CT001	EKG11CT002
HH In	99,0%	40,0	60,0	35,0
HH Uit	98,0%	35,0	55,0	30,0
LL In	35,0%	-5,0	1,0	1,0
LL Uit	40,0%	0,0	5,0	5,0
H1 In	95,0%	nvt		
H1 Uit	90,0%	nvt		
L1 In	45,0%	nvt		
L1 Uit	50,0%	nvt		
Regeling	EKG10CL001_LIC			
SP	60,0			
MAX	450,0			
MIN	0,0			
Opties				
Versterking P	0,0			
Gain	1,0			
Integratietijd I	20,0			
Differentiatietijd D	0,0			
	Watcher			
	Operator 1			
	Operator 2			
	DMT			
	Software programmer			

Figure 9 – Parameter list.

7.4.5. User levels

Analysing the final parameter list learned that the amount of different user levels differ from the amount shown in figure 9. There will be 5 different levels, each having different rights within the future user interface. The table below states each level and adds a corresponding colour the user level can be recognized with.

User level	Corresponding colour
Operator 1	
Operator 2	
DMT service	
DMT expert	
Safety	

Table 7 – User level colours.

User levels Operator 1 and Operator 2 will be used at the customer of DMT. Operator 1 can perform basic control tasks and change a minimal amount of parameter settings. Operator 2 has access to a few extra parameter settings and it is the intention that only a few – the more experienced – operators at the customer will use this level. The DMT service level is used by engineers and provides access to most of the PID settings to fully control the plant. DMT experts will have the addition of the ability to adjust most of the alarm settings and the required user level to change a parameter setting up to DMT expert level. The reason why there are two different DMT levels implemented in the system is because even DMT process engineers do not know every single plant from the top of their head and every plant is (a little) different. When a lesser-experienced engineer provides 24-hour service to the customer this user should not be able to change hard safety settings. The safety level has access to every setting and can change every possible required user level. Only the programmers of the SCADA system can access the safety level.

If a user decides to not login, they will not have access to any of the settings or features at all. Logging in will unlock these and their level of complexity is dependent on the user level that is assigned to them. Authentication is also required because features like the print screen function, the chat function and the data log require a users username as input for the data they save and present.

Dividing the users in to five different groups has multiple advantages. One of the most important is a safety issue. As read in the user and usage analysis (see section 4) there is only one level implemented in the current SCADA system. This level is used by both high and low-end users and could result in undesirable situations, usually caused by unintended mistakes made by low-end users.

For safety reasons there has been a timer built in the interface. Whenever a user has not been active within the user interface for a short amount of time – 10 minutes for example – the user will automatically be logged out. This does apply to every user level except for the Operator 1 level.

On the other hand there are some alarm settings that serve as hard safety for the PWS. Even DMT engineers – whether they are DMT service or DMT expert – should not be able to change these settings to secure safety at all time.

8. Final concept design

This section will explain every part of the conceptual design in detail and argue why the implemented features and design is chosen.

8.1. Framework

The framework of the final concept features several navigation elements and important information for the user. The window the frame is built in the aspect ratio 16:10 (1280x800). The top frame includes the following features:

- Menu button;
- General state;
- Alarm bar;
- Current user;
- DMT logo and frame colour;
- Quick stop button.

The bottom frame features buttons to navigate between the overview and the different subsystems of the plant. Figure 10 shows the visualization of the framework.

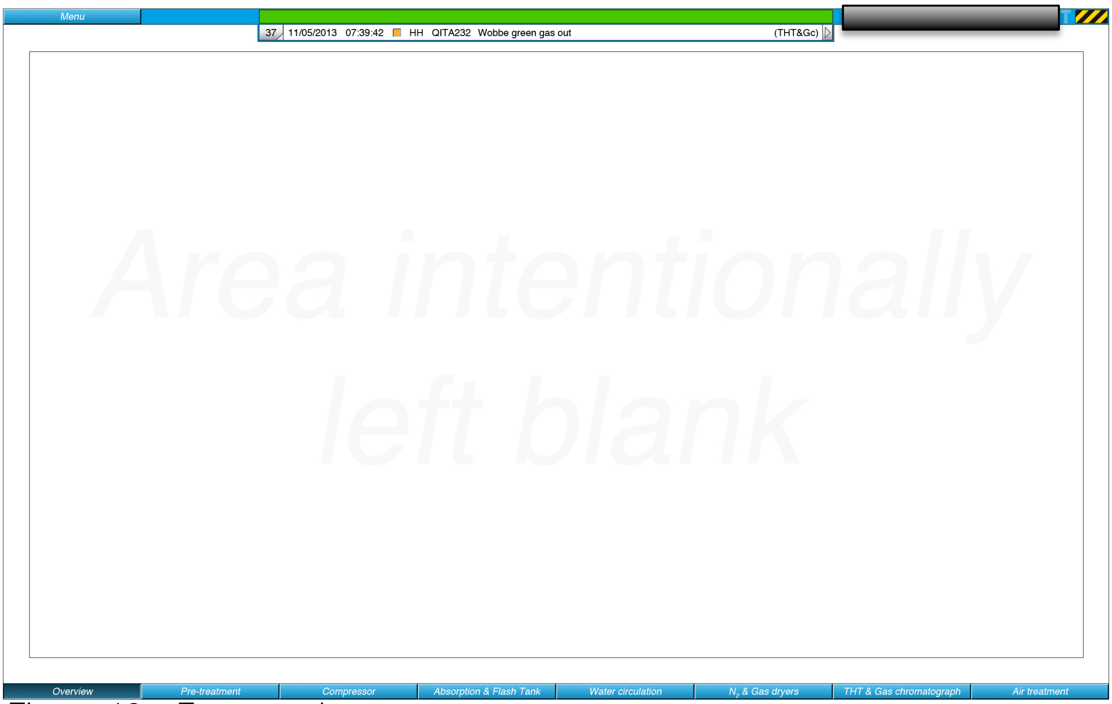


Figure 10 – Framework.

8.1.1. Top frame: menu

The menu button (Fig. 11) provides several features the user interface has to offer. The button is positioned at the top left of the user interface, similar to the ‘file’, ‘edit’ and other menu’s that are often used in popular computer software. Clicking the button will make it expand showing all possible options. Interface features the menu button contains are shown in figure 12. The colour of the button changes from light blue to dark blue indicating it as pressed. While navigation through the menu the current selection – by hovering over the option with the mouse – will turn blue. Clicking one of the menu options will fold the menu – making the menu button expandable again – and pop a window showing the clicked feature in the active area of the user interface. Clicking the cross button at the right side will hide all menu options and will make the button clickable and light blue again. The position of the cross button is another example of applying a habit to the redesign.

Figure 11 – Menu button.

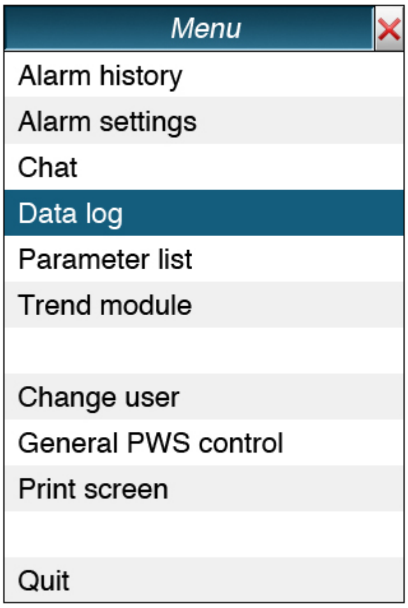


Figure 12 – Menu expanded.

A detailed description of all menu features will follow further this report.

8.1.2. Top frame: state bar

The state bar is a new feature to the user interface. The state bar will change colour to help a user to get a quick read on the current state of the plant. When the bar is coloured green the plant is running without any problems. An orange state bar indicates minor deviations and tells the user to check the process. The plant will could possibly shut down in the near future when the state bar turns red. The red state requires immediate action in order to get the plant running in stable state again.

The state bar is implemented because current interfaces did not visualise the overall state of the plant. At some customers operators will not be able to monitor the plant during the entire day. In between the different tasks they have to perform they will check up on the system. Therefore it is important to visualize the overall state of the plant in a clear way. This way an operator does not have to search the entire interface for small alarm or state indications as with the current user interface. Regardless of the current screen it is always possible to get a quick read of the current state of the plant. The size and positioning of the bar – wide bar in the top-centre of the screen – contribute positively to the meaning of the state bar. The table below clarifies the different states of the state bar (see Fig. 13).

State bar colour	Required action
Green	Stable-state: no actions required.
Orange	Notification-state: attention required.
Red	Action-state: action required.
White grey	PWS inactive.

Table 8 – State overview.


Figure 13 – State bar colours.

8.1.3. Top frame: alarm bar

One of the most important parts of the user interface is the alarm bar. This bar informs the user about the most recent alarm that occurred (see Fig. 14).

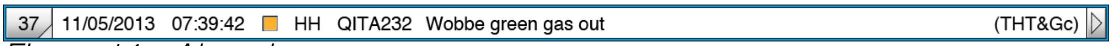


Figure 14 – Alarm bar.

The presented data in the alarm bar is logically ordered to make the notification easier to understand. The first two data types are the date and time the alarm occurred. The coloured box indicates the severity of the alarm (see Design preparations: Alarm severity). The next data type represents the alarm type (see Design preparations: Alarm settings) followed by the tag of the sensor that is causing the alarm. The description of the alarm followed by an abbreviation of the subsystem the alarm is located in conclude the information the alarm bar states.

At the front of the bar there is a button with the amount of outstanding alarm notifications. The icon – grey triangle – located at the bottom right of this button tells the user that the alarm bar is expandable. Clicking this button will expand the alarm bar frame, showing all active alarms (Fig. 15). The size of the frame will not cover the entire screen to prevent obstruction of the rest of the interface. The expanded alarm frame can show up to 15 notifications a time and users are able to mouse scroll down whenever the total amount exceeds 15. The example given in figure 12 shows 37 alarm notifications in total of which 15 are displayed. By using the scroll bar at the right side a user can view the remaining 22.

The text of the first 12 alarms of this example is coloured black and are still active. The other 3 are greyed meaning these alarms are not active anymore.

Users have the possibility to remove all inactive alarms from this list by clicking the 'Clear alarm button' at the top right of this window. The alarm notifications will not be removed from the Alarm history (see Final concept: Alarm history).

By pressing the 'Help button' users can get more information about all alarm notifications. In some situations this be extremely helpful including when certain features the system provides show very complex data. The positioning and visualisation of the help window is still something to develop for the future user interface. Only the possibility of a help button itself is taken into account in this advisory.

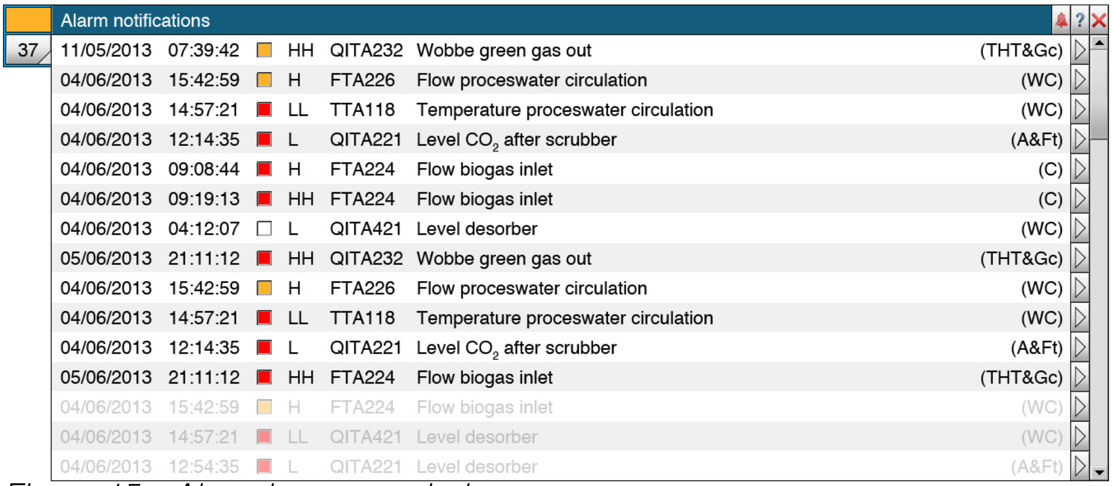


Figure 15 – Alarm bar expanded.

The 'Cross button' will close the expanded window leaving the interface with the single alarm bar. Every alarm has got a button attached at the right side of the concerning alarm. This 'Go-to button' creates a link between the (expanded) alarm bar and the position of the alarm in the user interface. Users often struggled finding the exact location of the alarm. When a user clicks the go-to button of the TTA118 Temperature proceswater circulation-alarm the alarm notification window will fold and the Water circulation (WC) subsystem will be shown.

The title bar of the expanded alarm bar will not fully obstruct the state bar. Users can still get a read of the overall state of the plant even if the alarm bar is expanded. Keeping the user informed at all time is an important factor of the redesign.

8.1.4. Top frame: current user

The top framework shows the name of the current user (Fig. 16). This is especially useful for the customer of DMT. Most of the time there will be one computer used to control the PWS and is used by several users with different user levels. Communicating the current user – and thereby user level – could help detecting the usage of a wrong user level. Preventing a user to use the interface that is currently in a higher user level than it should be is out of the range of interface design. Showing the current user at all time can only assist in preventing a user from using the interface when they should not be allowed too.

Figure 16 – Current user, DMT logo, frame colour and quick stop.

8.1.5. Top frame: DMT logo and frame colour

To give the user interface a DMT appearance the colour used for the framework is the same colour the DMT logo contains (Fig. 16). The interface does match with current flyers, posters and the DMT website (www.dmt-et.nl). The DMT logo is also implemented at the right side of the framework.

8.1.6. Top frame: quick stop

The 'Quick stop button' located at the far right side of the top frame will allow users to stop the installation from running in an irregular and immediate way (Fig. 17). The button is designed to clarify the consequences of its use. The yellow-black stripes are commonly used to notify something 'DANGEROUS!'. This design has a double meaning in this case. On one hand it serves as a quick stop to prevent dangerous situations, on the other hand it will warn the user about the negative effects of using the quick stop. Starting an installation after a quick stop will take way longer than a regular start.

In order to prevent users from pressing the quick stop button accidentally the process is divided in two actions. Clicking the quick stop button will expand the frame and give the actual stop button (Fig. 18). Clicking the button will stop the plant. Clicking anywhere else than the button will hide the expand frame again. The stop sequence is not the quickest but it will surely prevent accidental presses from happening. The extra action will only slightly increase time it takes to stop the installation.

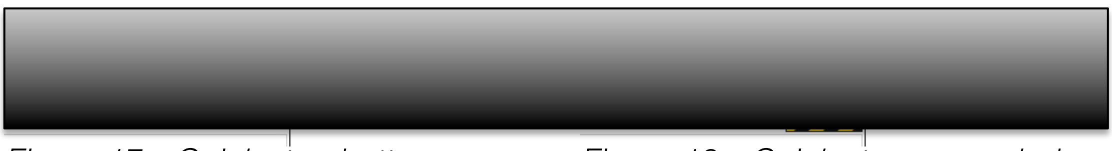


Figure 17 – Quick stop button. *Figure 18 – Quick stop expanded.*

8.1.7. Bottom frame: navigation buttons

The bottom frame provides 8 buttons to navigate between the different subsystems pages or the overview page of the PWS (Fig. 19). The navigation buttons are positioned at the bottom of the screen, simply because most users are used to this position for switching between different windows (or programs) on a windows based computer. Implementing this position ensures recognition for the user, making it easier to understand the general control of the interface.

Figure 19 – Navigation buttons.

By default the overview page is shown, making this button appear as pressed. Pressing a subsystem button will show that subsystem, making the corresponding button to appear as pressed and make the overview button accessible again. The difference in the appearance of the buttons ensure that a user can always see which window is currently active, keeping them informed at all time.

8.2. Framework decisions

Some important decisions that also influence the design of other screens were made during the design of the framework. The division of the plant in to 7 different subsystems is the first important choice. The second one is the visualization of the expanded alarm bar (i.e. the pop up window) and the abbreviations used to indicate the subsystems are the last decision. This section will briefly explain the decisions made.

8.2.1. Subsystem division

The PWS plant is a complex system and contains a lot of different parts. In order to ease the user in controlling the PWS the interface divides the plant in to multiple subsystems. The different phases of the upgrading process mainly determined the subsystem division. A second factor is the amount of parts a certain phase contains. The water circulation phase (see Background: the PWS) contains the absorption, flash and desorption vessel as well as all the pipes, valves and other parts making it too much to show on one page. Therefore the water circulation phase is split in to two parts. The first part (Absorption & Flash tank) contains everything that goes with – the absorption and flash vessel. The second part (Water circulation) contains the desorption vessel, water-cooling unit and every belonging part. The biogas post-treatment phase has also been split in two parts for the same reason. The first part contains the nitrogen unit and the gas dryers (N_2 & Gas dryers). The second part the odourisation unit and the gas chromatograph (THT & Gas chromatograph).

8.2.2. Non-parameter frame visualization and composition

The visualisation and build-up of every pop up window – whether it is an expanded or a whole new window – is applied in the same way as the expanded alarm bar frame (Fig. 15). The top bar of these windows have of a coloured bar with the title of this frame. The right side of the title bar allows the user to close the window or access features this specific window has to offer.

A scroll bar – when required – with the same height as the window will be attached to the right side of the frame positioned right beneath the close button.

The colour of the title bar of all non-parameter frames will be dark blue. This choice is made because on one hand it will suit the colour of the framework.

On the other hand it will show the window is independent and not a part of the framework.

8.2.3. Parameter and part frame visualization and composition

The colours of all parameter and part frames match the colour of the pipe (i.e. the matter) it is connected to. Users can easily look for all parameters associated with water by looking for the green parameter frames. The choice of matching these colours will help users to get a better understanding of plant. It will be easier to understand the meaning of a parameter and improve a users' overall performance. An overview of the pipe (and parameter frame) colours will be given in the following section.

A parameter frame that contains an error (alarm) can easily be spotted. The frame colour will turn red (if urgent) or orange (non-urgent) when there is something wrong with any of the PID settings of this parameter.

8.2.4. Subsystem abbreviations

One of the data types the alarm bar provides is the subsystem the alarm is in. To indicate this location an abbreviation for the concerning subsystem is used to prevent the alarm bar from being too full of information and therewith disturbing. The abbreviation takes up little space and it is expected that every user will understand its meaning. The following table shows the 7 abbreviations used to indicate a subsystem.

Abbreviation	Subsystem
(Pre)	Pre-treatment.
(C)	Compressor.
(A&Ft)	Absorption and Flash tank.
(WC)	Water circulation.
(N_2&Gd)	N_2 & Gas dryers.
(THT&Gc)	THT & Gas chromatograph.
(Air)	Air treatment.

Table 9 – Abbreviation overview.

The abbreviations will also be used in the visualization of several job assistance features the interface will offer. These features will be explained later this report.

8.3. PWS representation

The largest part of the screen will be covered by the representation of the PWS and shows the overview or one of the subsystems (see Final concept: Framework decisions). This section provides all different PWS parts the user interface is built of, followed by a recommendation for the overview and subsystem pages.

8.3.1. PWS vessels

One of the most important parts to display is the vessels of the PWS. In current user interfaces vessels were shown very small and flat, making it look like an undervalued part of the system. These parts must certainly be present in the future without demanding too much attention. Components can be visualized in 3d or 2d representation. Both ways are shown in figure 20.

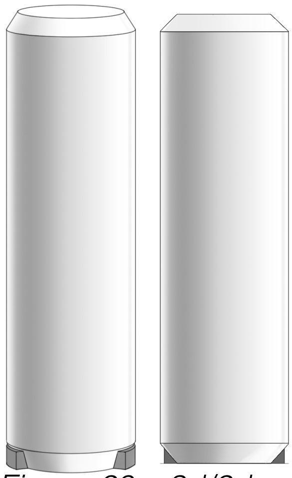


Figure 20 – 3d/2d vessel representation

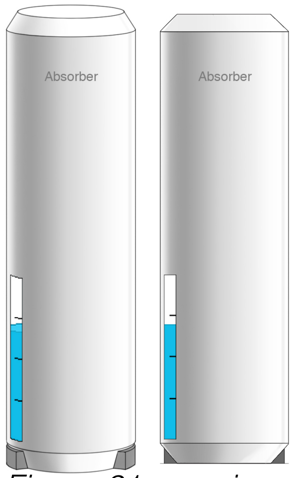


Figure 21 – equipped vessel.

The 3D, as well as the 2D representation, gives a 3-dimensional effect because of the applied gradient, the darker bottom and the brighter top. This way the part will be more striking in comparison to a flat image.

Figure 21 shows the vessel equipped with the title of the part and a fill indicator. Because each part is a little different the name of the part will be shown in the top to clarify its meaning. The colour of the title will be grey, matching the part colour, to demand as little attention as possible. The 3d representation looks better for sure but does not really contribute when the title of the part is given. The overview page will show at least 8 parts. The 2d representation ensures a clear view and less noise on the screen. Some vessels will indicate for what percentage they are filled. This fill indication is positioned at the bottom left of the concerning part.

8.3.2. Other components

The PWS also consists of other components like the compressor, cooling, nitrogen unit and odourisation unit. Because these parts are all very different from each other or exist of multiple parts, a black box part will be used. The title will explain whether this part is the compressor, cooling or another part of the PWS (Fig. 22). The visualization of the black boxes does match the visualization of the PWS vessels.

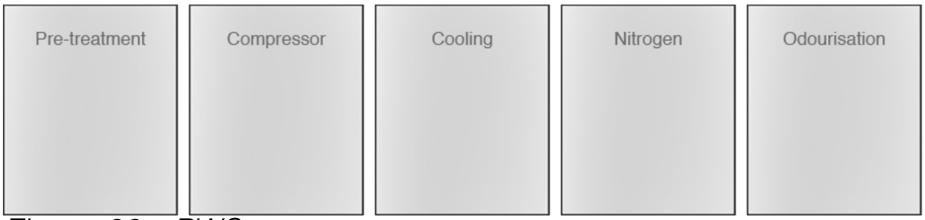


Figure 22 – PWS components.

8.3.3. Valves, compressors and motor

The plant also includes valves, compressors and motors. Up to now those parts were usually visualized by a basic and flat icon. Because these parts are most certainly important to the PWS they are made striking (Fig. 23). The top part of figure 20 represents a valve, the second one a compressor and the bottom one a motor. The appearance is derived from PID's.

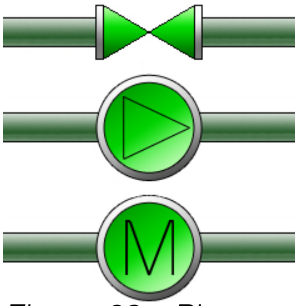


Figure 23 – Pipe parts.

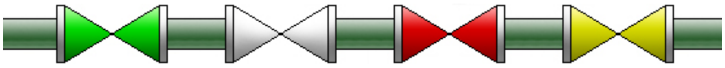


Figure 24 – State indication of a valve.

The colour of a valve, compressor or motor is variable and indicates its current state (Fig. 24). The table below shows the different colours and the associated state.

State colour:	Part state:
Green	Automatic mode and opened.
White grey	Automatic mode and closed.
Red	Alarm mode and opened.
Yellow	Hand control mode and state independent.

Table 10 – Overview of different part states.

Users can access information and settings by clicking the part resulting in a pop up window positioned at the bottom right of the part (Fig. 25).

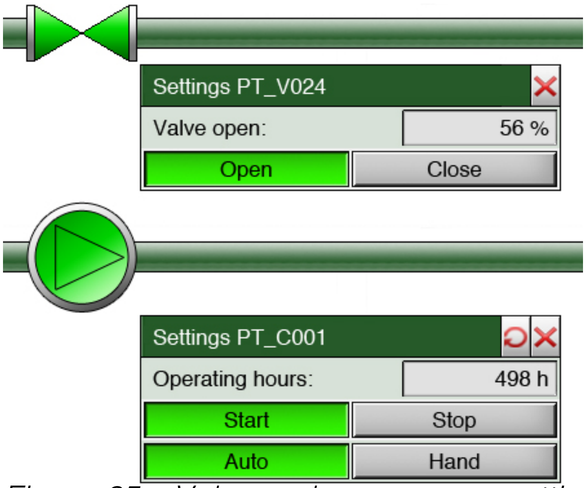


Figure 25 – Valve and compressor settings.

The valve settings (PT_V024) show the percentage the valve is opened. The grey text field showing the percentage is greyed out because the parameter is not editable. The settings frame also gives the control option to open or close the valve. An inactive state button will always be grey. The open, start and auto buttons will be green when active. The close and stop buttons will be white grey and the hand mode button will turn yellow if pressed.

The compressor settings (PT_C001) shows the current amount of operating hours and gives a user the option to start or stop the compressor or set the operating mode to automatic or hand controlled. 

Whether a user is allowed to use the control options is dependant on their user level. The same is applied to the 'reset operating hours button' (Settings

PT_C001 frame) or other features part settings might provide. Pressing a button while a user is not authorized to won't have any effect.

The pop up window will always appear at the same position but this position won't be fixed. Clicking and holding the title bar with the left mouse button followed by moving the mouse will reposition the frame. When the frame will be closed and reopened again the position of the frame will be at the default location.

8.3.4. Pipes

The visualization of the pipelines connecting the PWS parts together is of great importance for the user interface. Designing the pipes too thick demands a lot of attention and thereby creates a lot of visual noise. Connecting the parts with a very thin line won't be realistic and will cause ambiguities in the representation.

The pipelines as used in the final concept are shown in figure 26.

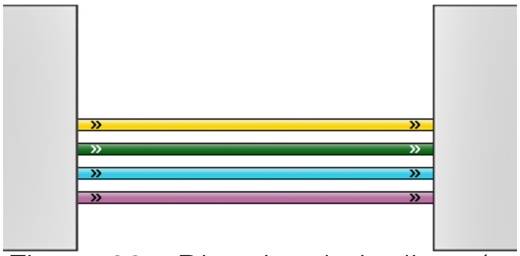


Figure 26 – Directional pipelines (gas, water, air & N_2, THT).

The small arrows inside the pipeline indicate the direction of the gas flow, water flow or flow of any other matter. The first indication is positioned at a fixed distance from the part it comes from and the second one to where it leads too. The colour is determined on the basis of the NEN3050 standard. Consistent use of this standard prevents confusion, especially for DMT engineers that might work with different interfaces on a daily basis. Colours derived from the NEN3050 standard that are directly related to the PWS interface are listed in the table below.

Pipe colour:	Matter:
Yellow	Gas.
Green	Water.
Blue	Air and nitrogen.
Purple	THT.

Table 11 – Pipe colours/matter.

8.3.5. Parameter frames

The PWS interface provides a lot of parameter frames to inform and offer the user options to control the process. As previously mentioned, the colour of the parameter frames will match the associated matter (see table above) to create a clear view and understanding of the plant. Parameters concerning a gas can easily be identified, just by looking at the yellow parameter frames. The title of the frame will give a brief description of the parameter. The parameter itself is stated below (Fig. 27). The parameter is connected to the pipes by a dotted line, indicating a relation between the two parts.

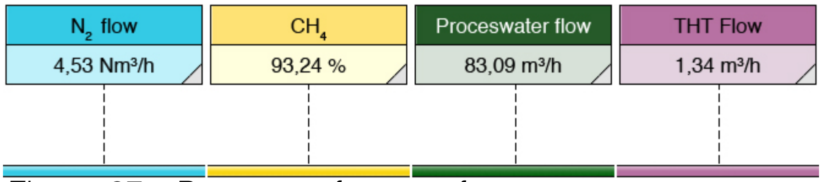


Figure 27 – Parameter frames of every matter.

Clicking the parameter frame will pop window at the right side of the frame. This expanded parameter frame will give access to the alarm and PID settings related to the parameter (Fig. 28). Whether a user can change a certain parameter settings is dependant of their user level. The value box of settings that cannot be changed will be greyed out. Settings that are accessible will have a white value box. To change a setting users can simply click on the value box and enter the desired setting. The parameter settings offer several job assistance features to improve a user's ease.

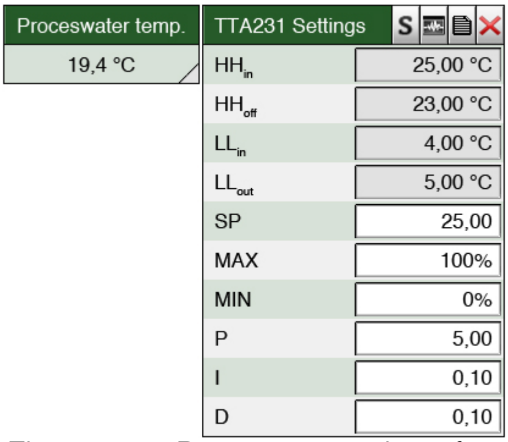


Figure 28 – Parameter settings frame.

Simulation mode:
The first feature is the simulation mode where parameters can be marked as simulated. A reason to use this feature is when a user enters a value to test the influence of the change on the upgrading process. Of course there are way more situations where the simulation feature will become useful. Authorized users can click the 'simulation button' at the top right of the parameter settings window. Pressing it will show checkboxes in front of every setting. Checking a parameter will visualize the value box as simulated. The expand icon – grey icon – in the main parameter frame will also change appearance. The expand icon and the value box of simulated parameters will be yellow of colour. Figure 29 visualizes this sequence.

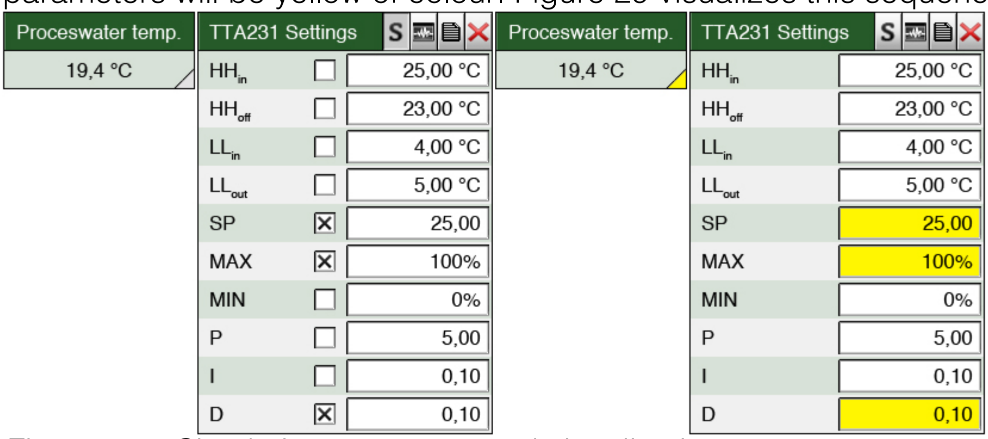


Figure 29 – Simulation sequence and visualization.

To disable the simulation of a parameter the checkbox in front of the parameter setting can be unchecked.

Graph:

Clicking the 'graph button' will pop a new window next to the parameter settings frame (Fig. 30). The graph will show the trend of this parameter during a certain amount of time. Graph settings can be changed to refine the range of the shown curve. A detailed development lies outside the scope of this report.

The graph and parameter settings windows will always appear at the same position but this position won't be fixed. Clicking and holding the title bar with the left mouse button followed by moving the mouse will reposition the frame. When the frame will be closed and reopened again the position of the frame will be at the default location. If there is no space at the right side of the expanded parameter frame, the graph will be opened at the left side of the (non expanded) parameter frame.

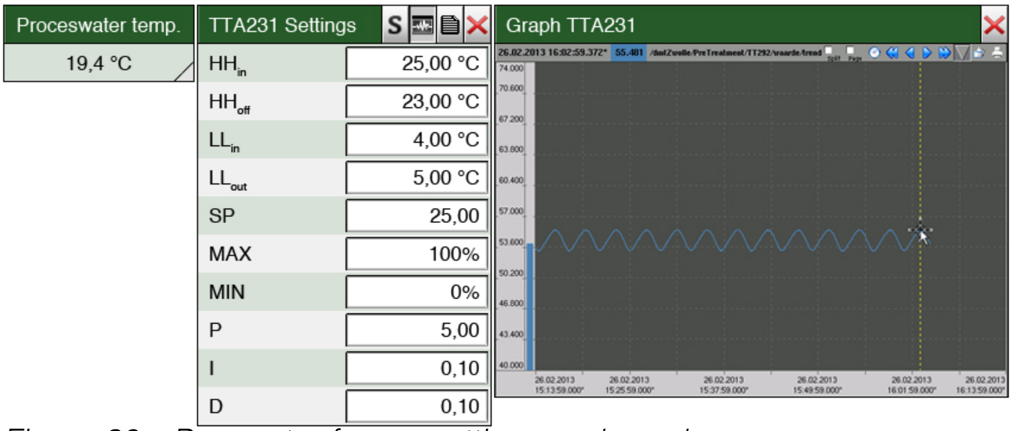


Figure 30 – Parameter frame, settings and graph.

Data log:

The parameter settings frame provides a link to the data log feature. Clicking the 'data log button' will close the parameter settings frame and show the parameter in the data log. This way a user can easily search for changes that are made to a certain parameter in the past. A more detailed description of the data log feature will follow in the remainder of this report.

8.3.6. Grid

A grid is made in the active area where the overview and subsystems will be positioned (Fig. 31). The grid serves as guide where all the parts, pipes and parameter frames will be placed in. Aligning the pipes to the gridlines will reduce the chaotic representation and improves ease of use.

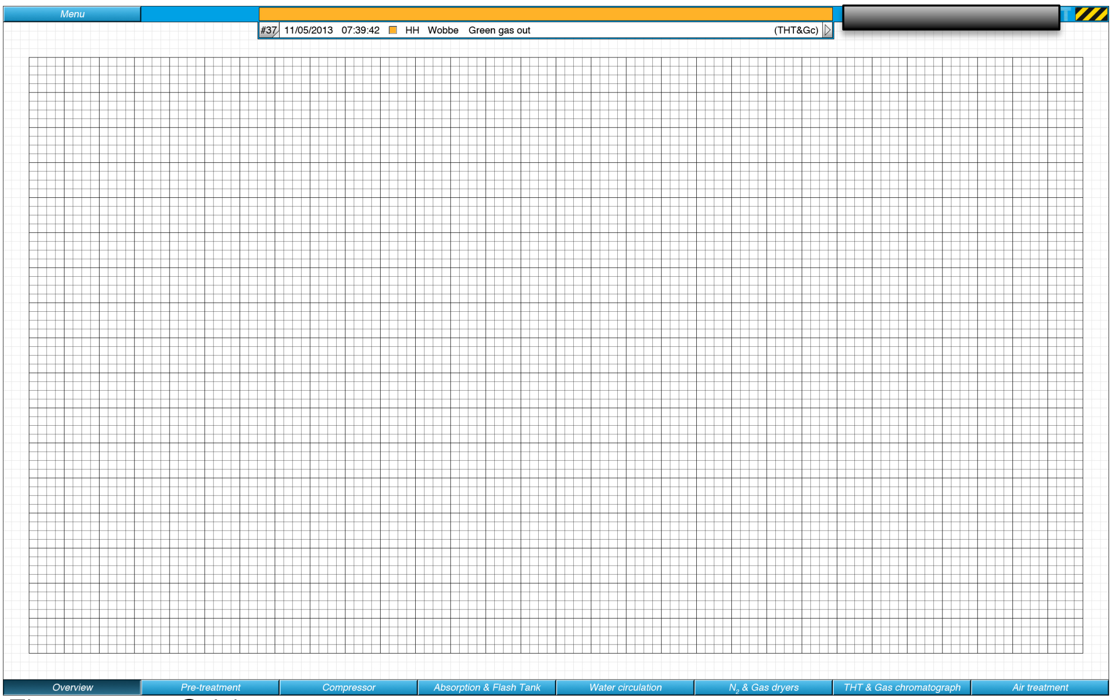


Figure 31 – Grid.

All parts explained in the Final Concept section will be implemented in the overview and subsystem pages. The following section will explain the recommendation concerning the Overview page and the Absorption & Flash tank subsystem.

8.4. PWS Overview page

The overview page of the plant is built of the most important parts of the PWS and all associated pipelines and parameter frames are connected. Figure 32 shows the final concept of the overview page.

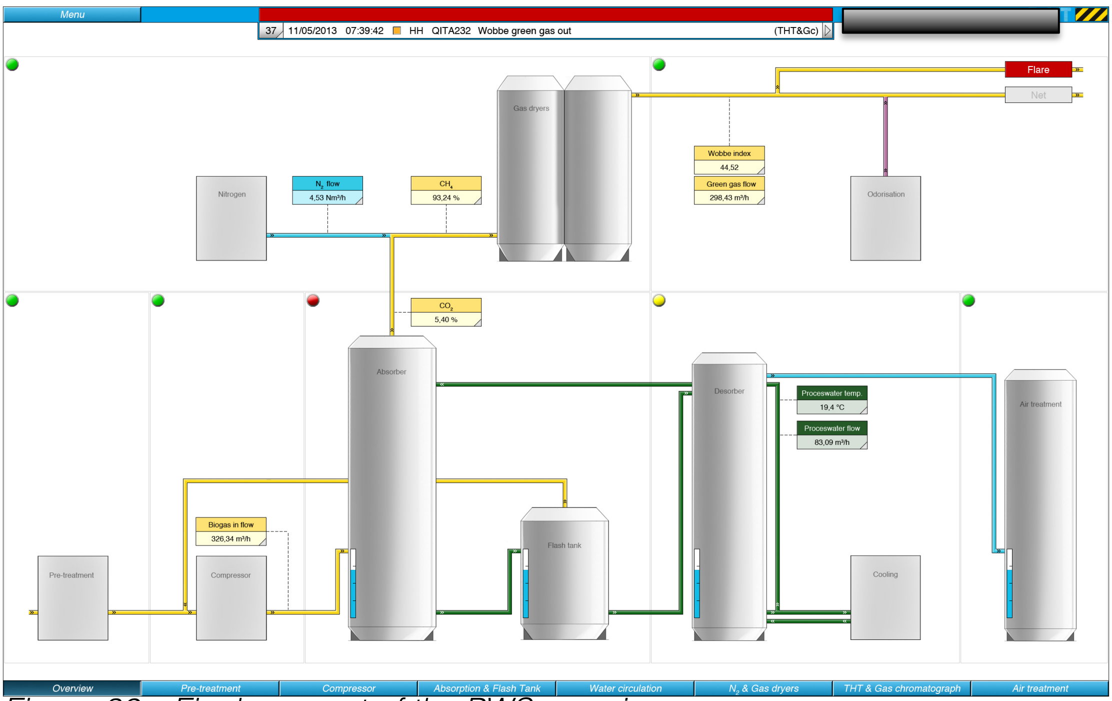


Figure 32 – Final concept of the PWS overview page.

The biogas enters the interface on the bottom left and leaves at the top right. At the absorber the process is split in to the top – the post treatment – and the bottom – the water circulation and air treatment – part of the representation. There are many different ways the PWS parts could be placed (see Appendix B). The placement in figure 32 is has come out on top because of the clear division of the gas and water part. Another benefit is that pipelines do not cross each other, which creates a clear and understandable view.

The 8 parameters frames on the overview are specifically chosen because these tell the most about the overall upgrading process. Operators obtain all information they need about the general upgrading process by reading these parameters. These parameters include the control possibilities operators have to make minor adjustments to the upgrading process.

The division of the subsystem is reflected in the overview. The planes surrounding the different parts each indicate a subsystem. Clicking inside one of the planes will show the associated subsystem. The subsystem titles are not displayed within the plane because this will only provide double information. The plane division is meant to provide clarification of the division of the plant. Users know which parts to expect when they access subsystem.

The overview page includes two job assistance features. The first feature clearly states if the produced gas is sent to the flare or to the net. The other feature indicates the state of a subsystem and offers a control feature.

Flare & Net indication
The flare and net indication is a simple visualization to indicate if the gas is burned or sent through the net. The flare indication turns red when active, leaving the net indication white grey (Fig. 32). If the net indication is active it will be green, leaving the flare indication white grey (Fig. 33).

Just as the state bar the flare and net indication will provide useful information that could be obtained directly. Users will no longer have to search the interface to get this type of information.

Subsystem state and control
The indications positioned at the top left of the subsystem plane inform the user about the current state of a particular subsystem (Fig. 33). The following table clarifies the different states of the subsystem indications.

Indication colour:	Subsystem state description:
Green	Full automatic mode. No alarms.
Red	Automatic or hand control mode. Alarm in this subsystem.
Yellow	Hand control mode. No alarms
White grey	Subsystem turned off.

Table 12 – Subsystem state colours.

Clicking the indication will pop a window at the bottom right side of it. This frame provides access to the general control of a subsystem (Fig. 33). This way a user has the possibility to control the plant from the overview page (i.e. start or stop individual subsystems and switch the control mode between automatic or hand). Whether the user can change the control of a single subsystem is dependent on their user level. Making this feature accessible for all users and provide full control from the overview page is one of the wishes for the future PWS user interface.

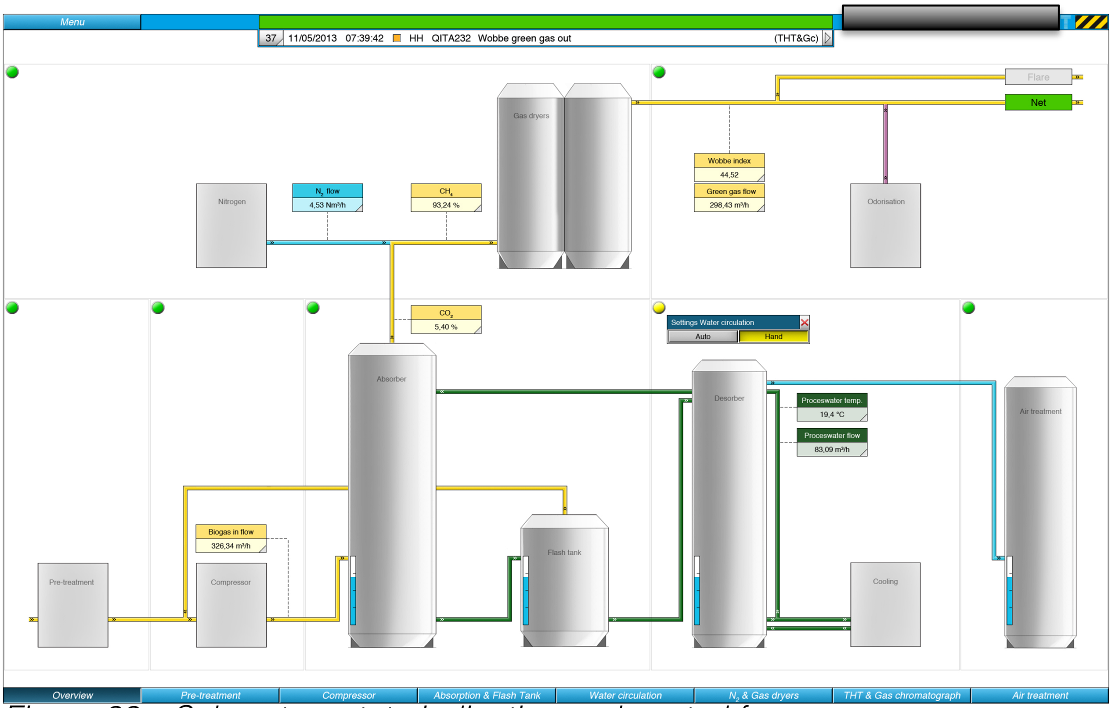


Figure 33 – Subsystem state indication and control frame.

8.5. PWS Subsystem page

To explain the implementation of all subsystems the Absorption & Flash tank subsystem recommendation has been made. This subsystem consists of the absorption and flash vessel, multiple valves and several parameter frames. The Absorption & Flash tank representation is shown in figure 34.

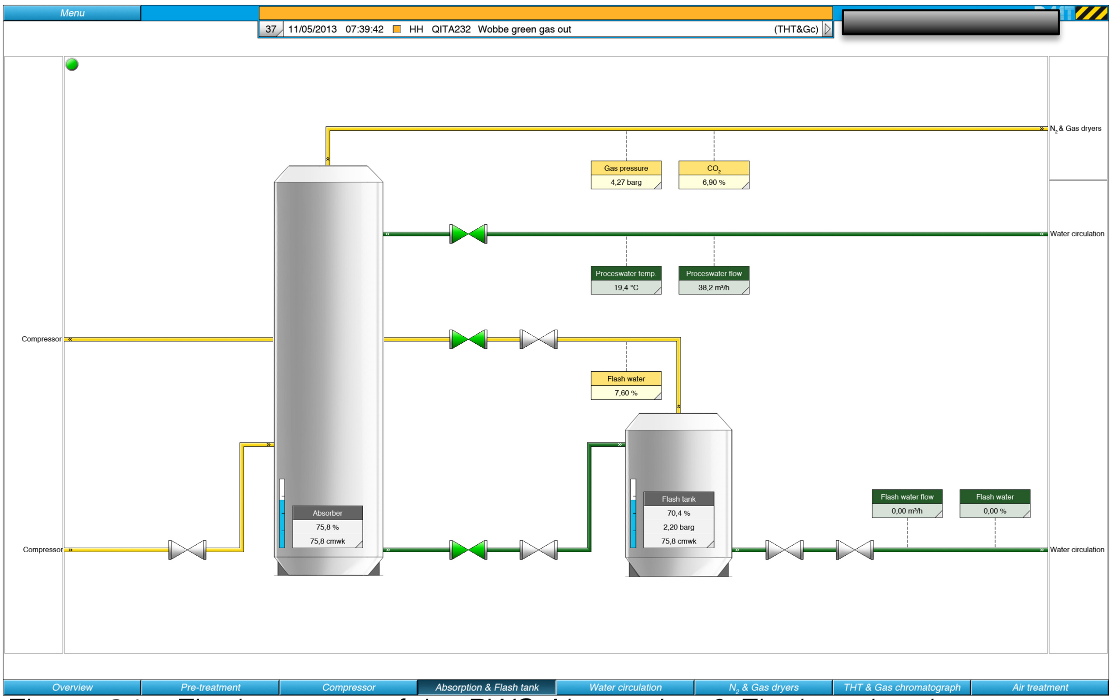


Figure 34 – Final concept of the PWS Absorption & Flash tank subsystem.

The in and output of the subsystem will enter or leave the screen at the left and/or right side. The subsystem abbreviations will tell to which subsystem the pipeline leads. The planes visualized at both the left and right side of the subsystem creates a link between the current and other subsystems. Clicking anywhere inside one of these planes will show the concerning subsystem. This way of providing plant information will give the user the exact amount of information they need without undesirable interface elements on the screen.

The absorber and flash tank are featured with a parameter frame showing the collected data concerning the vessel itself. This parameter frame acts the same as any other parameter frame.

The overall state of the subsystem is shown by the indication at the top left of the subsystem. This indication is exactly the same as the indication located at the overview page (see Final Concept: PWS Overview).

8.6. Job assistance features

The SCADA user interface provides several features to assist a user in performing a task faster and make it easier. These features can be found under the 'Menu button' at the top left of the user interface. Most of the time the PWS overview (or subsystems) will be used, therefore all additional options could be hidden behind a layer. Placing all features under the menu button will keep the interface clean and will only require the user to take a single extra action to access them. The user interface offers the following features.

8.6.1. Alarm history

The alarm history page shows the history of all alarms, showing the most recent occurred alarm on the top (Fig. 35). The order of the information is consistent to the information in the alarm bar. The only difference is the addition of the date and time the alarm is solved, providing extra information that could be useful in future. The alarm history will contain many alarms. The scroll bar at the right indicates that a user can scroll down to view alarms that occurred further in the past.

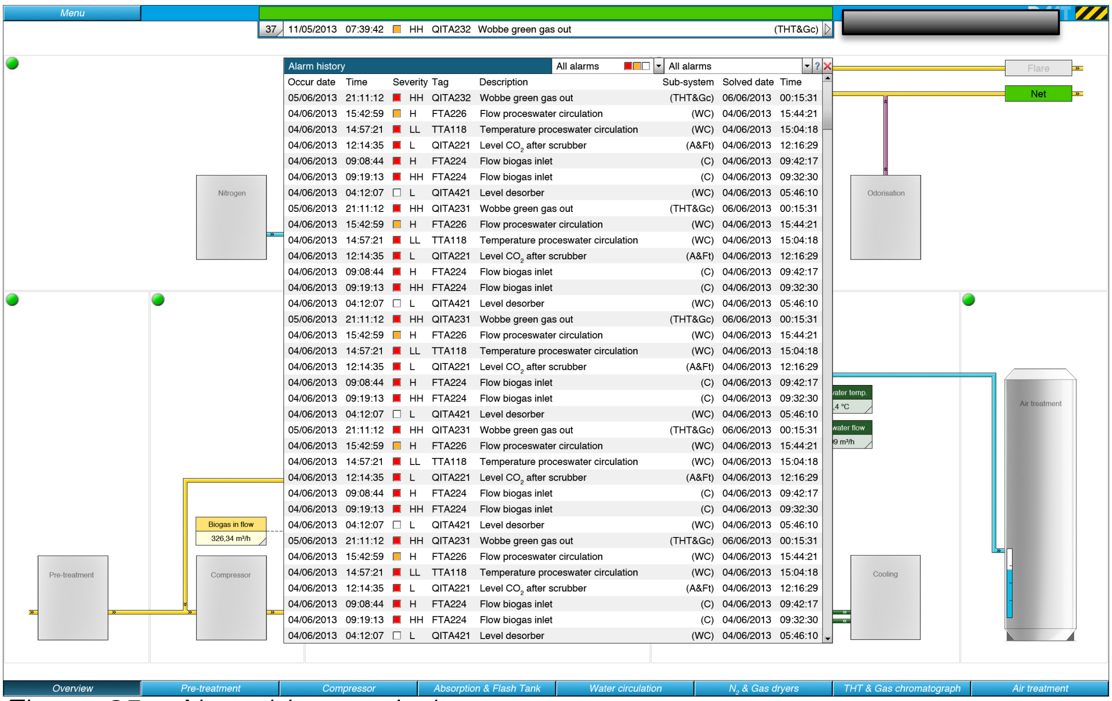


Figure 35 – Alarm history window.

To view all alarms of a specific subsystem the alarm history offers a filter feature at the right side of the title bar (Fig. 36). Clicking the ‘arrow button’ at the right side of the current sub system will make the window expand where users can choose the desired filter. To refine the given history even more users can filter alarms on severity using the second drop down menu. Searching for alarms in a subsystem and discover their relations will be a lot easier using this concept.

Another possibility would be to implement a search feature in the title bar where users can enter their own search terms. The alarm history will then show all matches to the entered terms. This way a user can refine a search as much as they want without having to search for an alarm in a long list.

Implementing a search feature will also have some downsides. First of all the amount of programming will increase significantly increasing the overall costs of programming the interface by quite a bit. Second the fixed refine filters won’t be as applicable as before. Restricting users to predetermined options will prevent users of making mistakes while maintaining flexibility.

The final concept implements the two predetermined filters users can apply.

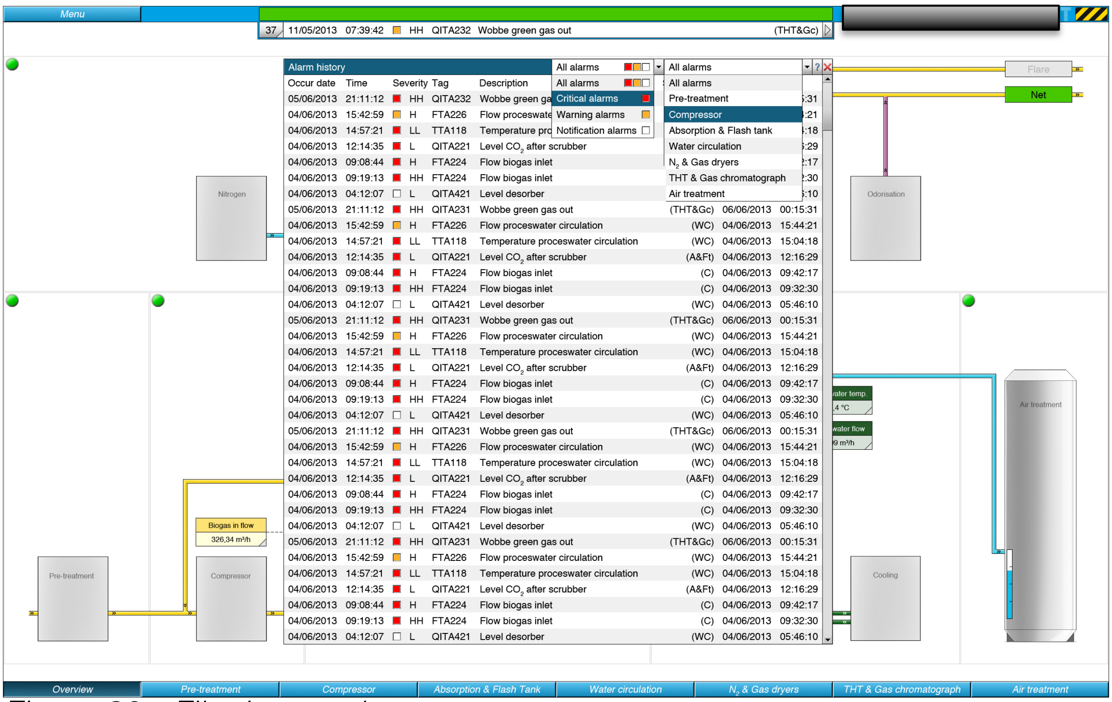


Figure 36 – Filtering results.

8.6.2. Alarm settings

The second feature the menu provides is the alarm settings page. This page lists all sensors and all their alarm types (Fig. 37). Users can view the severity setting of a specific alarm and change this setting if authorized. The order the different data types are shown is consistent to previously used arrangements. The tag, description and subsystem are always shown in this order. The severity and the alarm type are always coupled as well and will always be shown next to each other.

Choosing a filter in the title bar refines the shown options. Scrolling down will show additional options.

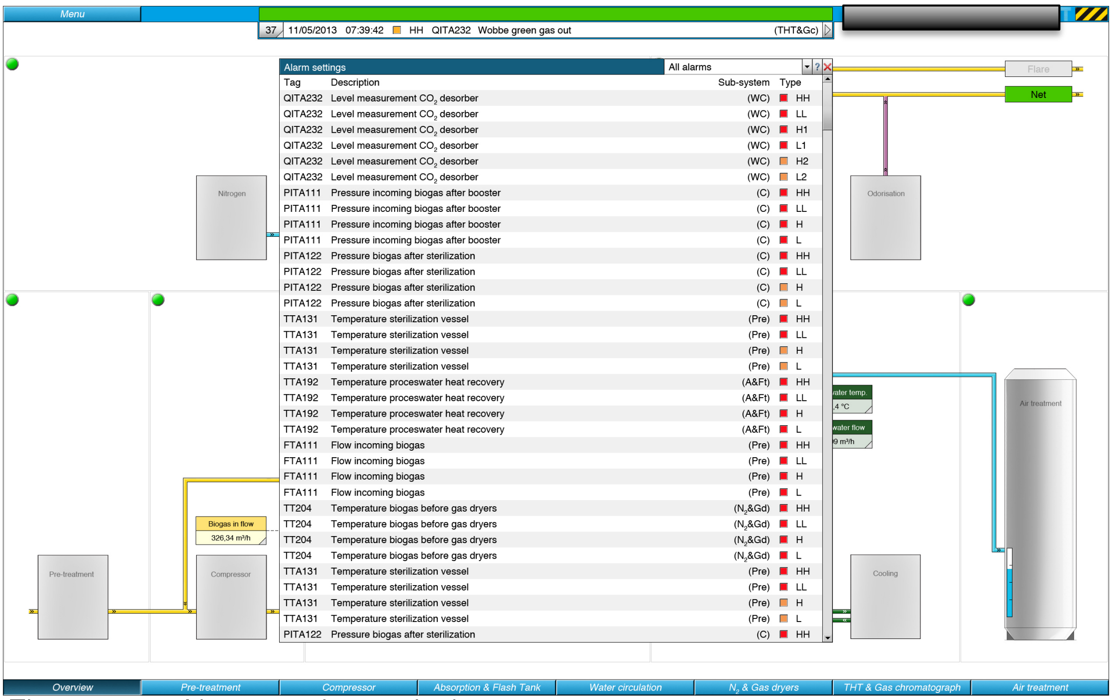


Figure 37 – Alarm settings window.

If a user is able to change the severity setting of an alarm the expand icon – equal to the one in the alarm bar and parameter settings – will be visible and positioned at the bottom right side of the severity indicator (Fig. 38).

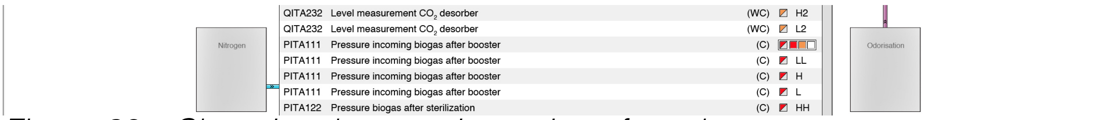
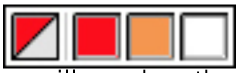


Figure 38 – Changing the severity setting of an alarm.



To actually change the settings, users can simply click on the severity indicator. Clicking it will show the possible options the setting can be changed to and clicking one will make the change. Clicking anywhere else in the alarm settings window will hide the possible options. Whether a user can change the alarm settings is dependant on their user level.

Changing alarm settings will not happen very often. The option will improve the overall performance of the user interface and therewith ease the user.

8.6.3. Chat

One of the all-new features is the chat function. This is especially useful when the SCADA system allows multiple users at the same time. The chat window shows a list of online users – including their user level – in a small window attached to the top right of the chat window (Fig. 39). The closed online user window can be reopened by clicking the 'user button' at the right side of the title bar of the chat window.

Users can write a message by typing it in the bar at the bottom of the screen. Pressing enter – or clicking the button at the right side of the chat bar – will send the message. The message will automatically be titled with the current date, time and the name of the user. Chat messages that have been read will be greyed out to clarify the difference between new and messages that are out-dated.

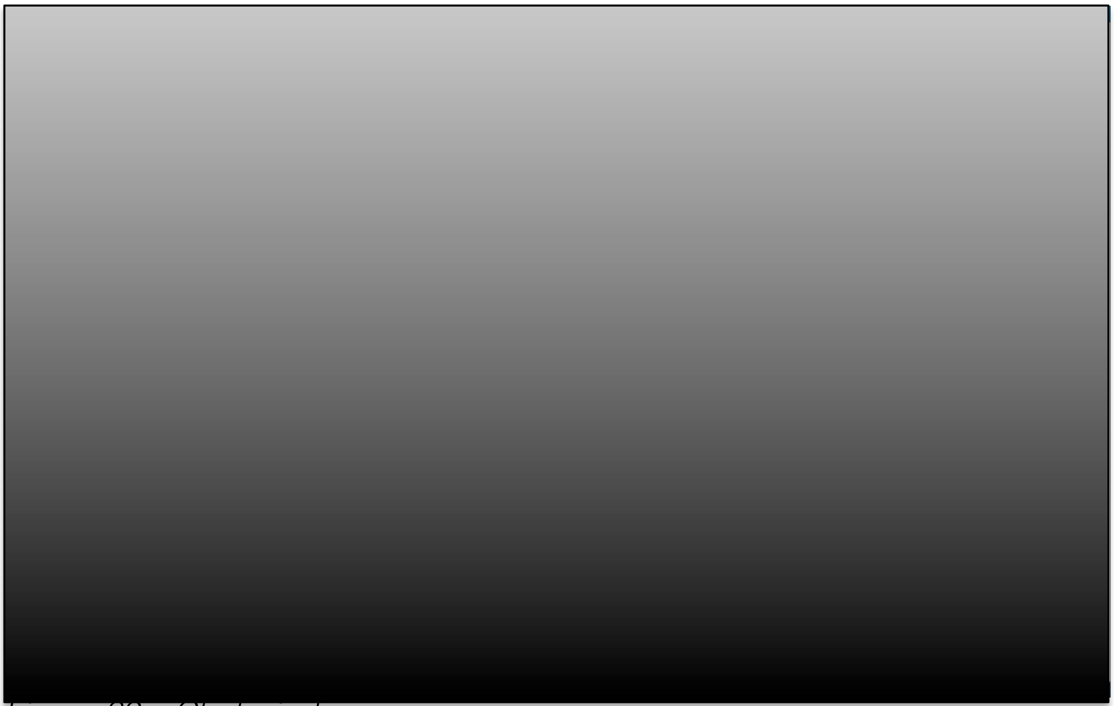


Figure 39 – Chat window.

A notification icon at the menu bar and in the menu itself will notify a new message (Fig. 40).

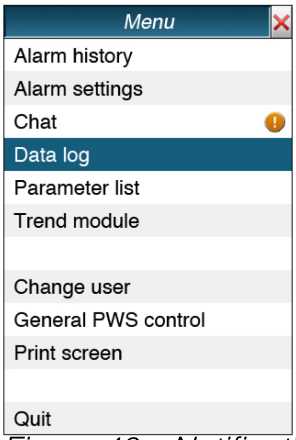


Figure 40 – Notification of an unread message.

8.5.4. Data log

Another new feature keeps track of all changes made in both the PID and alarm settings. Whenever settings are changed the SCADA system automatically logs this change in the data log (Fig. 41). The data log page shows a lot of different data concerning a change. The data is ordered in the following order:

Date – Time – Tag – Description – Subsystem – Type – Factory – Previous – Current – User – Notes.

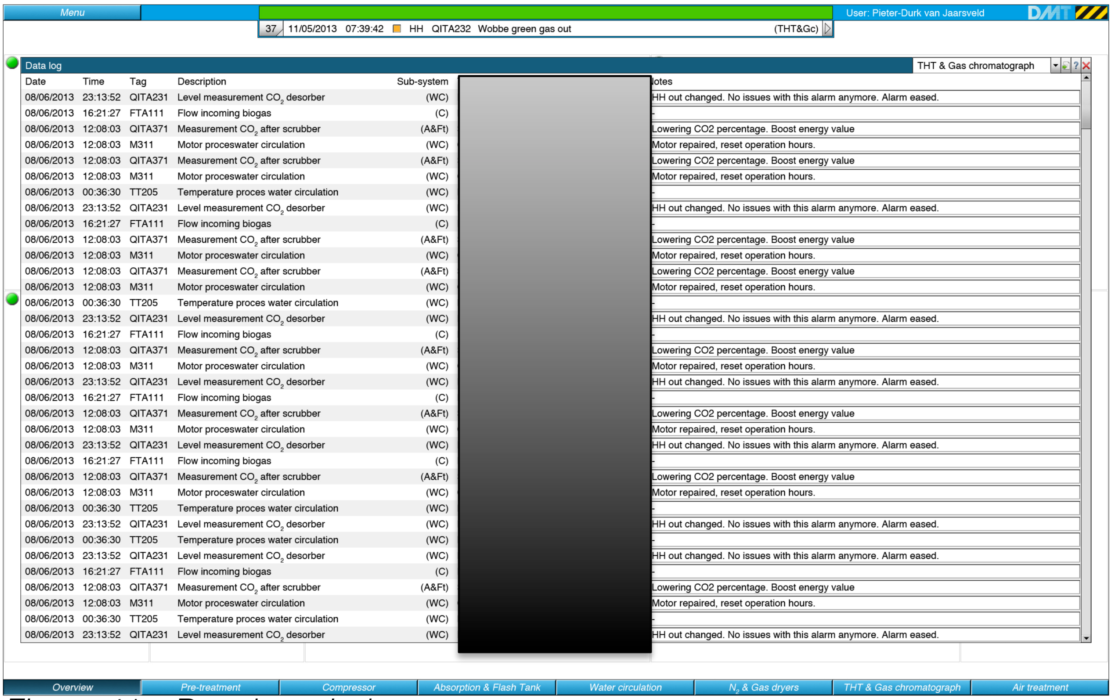


Figure 41 – Data log window.

The date, time, tag, description and subsystem provide general information. The type indicates the specific parameter setting that has undergone the change. The factory, previous and current box give information about the value of the parameter setting. The factory setting indicates the default value of the corresponding setting and is included to clarify the difference between the factory, previous and current value. The initials of the user that made the change are also included in the data log and right next to it there is room for a user to leave a note. Adding the user and leaving a note to explain the reason for the change that has been made avoids ambiguities and improves the overall performance of the process.

The data log only serves as informative display. Values given in de log cannot be changed. To change the settings of one of the parameters a user should access the parameter frame settings within the interface or the parameter list (see section 8.6.5.).

Choosing a filter in the title bar refines the presented data. Scrolling down will show additional options.

A useful addition to the data log will be an export function to save the entire log as an excel file that can easily be analysed or printed. The 'export button' has been implemented in the title bar. The operation after clicking the button is not included in this report and still has to be developed.

8.6.5. Parameter list

The parameter list feature shows the current value of every parameter setting the PWS contains and will be mainly used by engineers. Current PWS user interfaces do not provide a parameter list. Engineers use an excel file to get an overview of all current parameters instead. The implementation of the parameter list will be very useful because the data will always be up to date.

The order of the presented data starts with the default tag-description-subsystem order followed by the associated alarm and PID settings (Fig. 42).

Figure 42 – Parameter list window.

Figure 42 shows that some value boxes white and some are greyed out. This indicates which parameter a user can change. Grey fields are not accessible where white fields grant access. Whether a user can change a parameter setting is dependant of the user level.

Choosing a filter in the title bar refines the parameter list and scrolling down will show additional parameters.

Besides changing (or just checking) parameters settings, the parameter list also includes the required user level to change the associated parameter. Clicking the ‘eye button’ at the top right of the parameter list window will show the user level indications in front of the value box of every alarm or PID setting (Fig. 43). The used colours correspond with the user level colours as stated earlier this report.

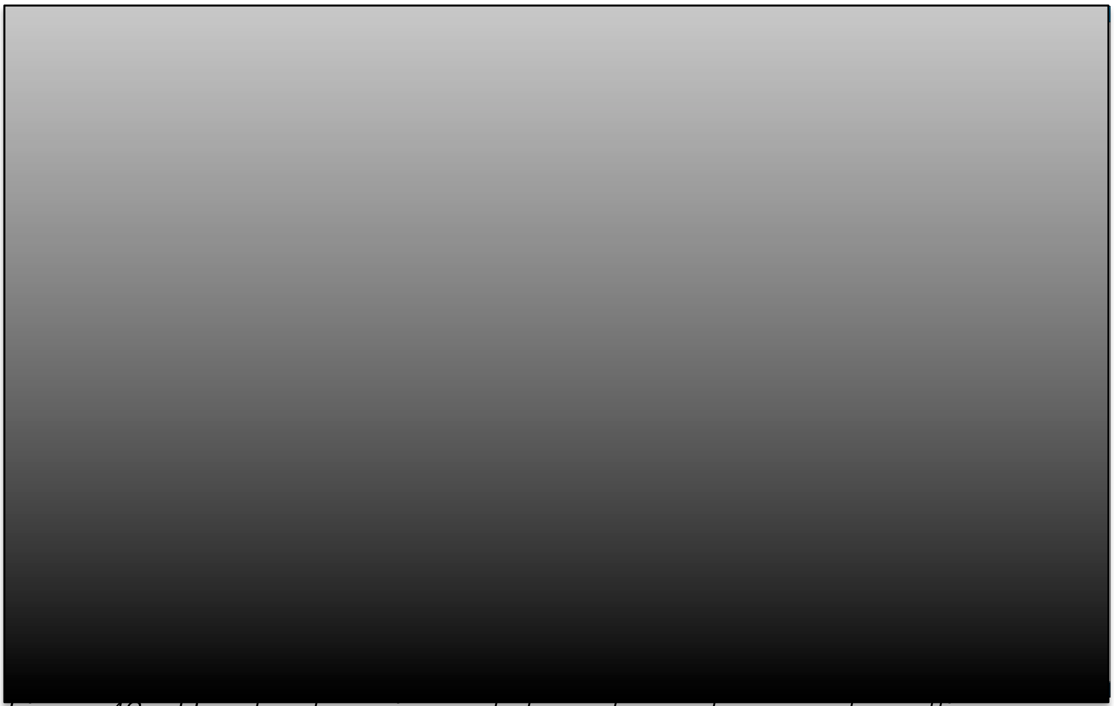


Figure 43 – User level requirement shown for each parameter setting.

It is recommended that only Safety level users can change the minimal required level a user needs to change a parameter setting. If a user is authorized to change the required user level the expand icon will be placed at the user level indication. To actually change the required level, users can simply click on the user level indicator (Fig. 44). This will show the possible options the level can be changed to and clicking one will make the change. Clicking anywhere else in the parameter list window will hide the possible options again. Whether a user can change the alarm settings is dependant on their user level.

Figure 44 – Changing the required user level.

The parameter list window also offers a feature to overwrite the current factory settings. It can occur that some factory parameter settings may change over time. These settings can be overwritten by with the 'save settings button' at the top right of this window (Fig. 43). It is recommended that only DMT experts and users with the Safety level can use this button.

8.6.6 Trend module

The trend module for the future interface has not been designed leaving this for future research. It is possible to implement the current trend module in the final concept. It is recommended to place the trend module within the framework of the large pop up window (Fig. 45).

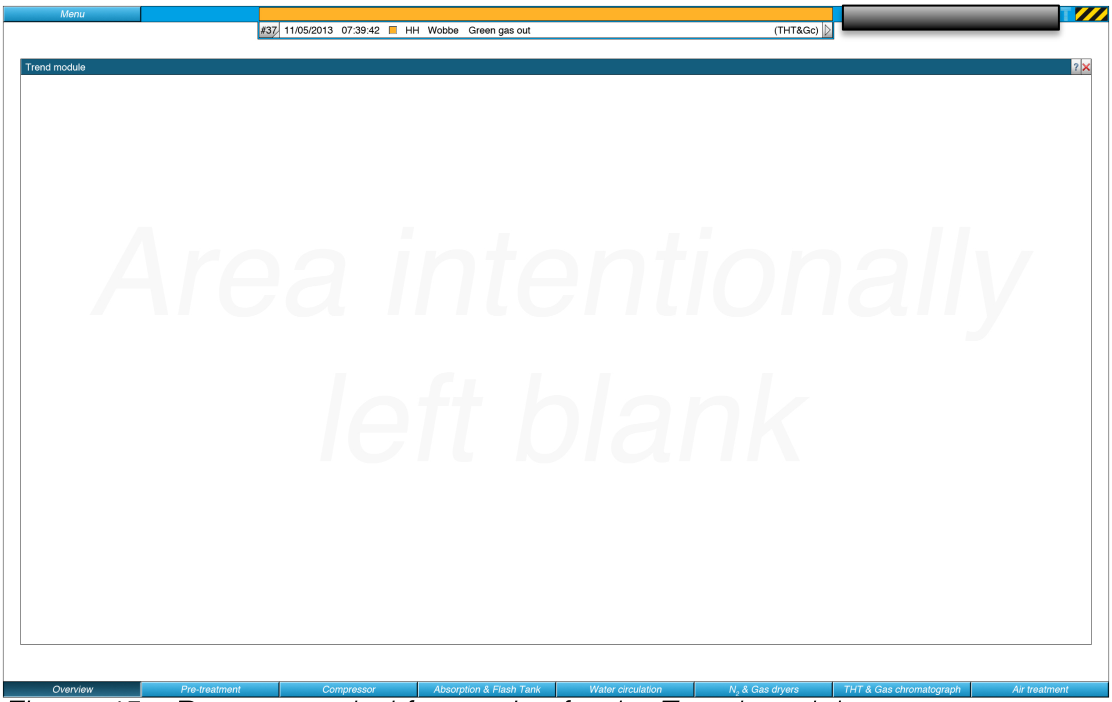


Figure 45 – Recommended frame size for the Trend module.

8.6.7. Change user

The menu provides the option to change user levels. Selecting this option will pop a small window at the top left of the screen asking for a username and password (Fig. 46). Entering the right credentials will change the current user. The user authentication window is positioned at the top left of the interface, close to the menu option to show this feature.

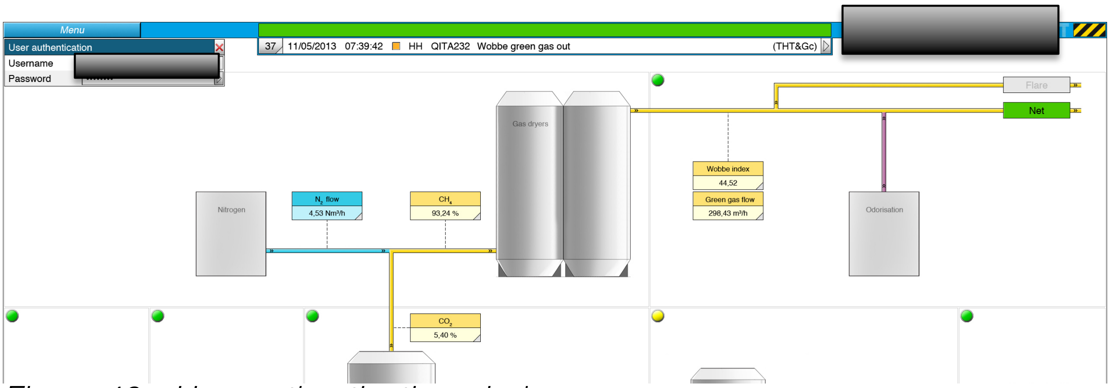


Figure 46 – User authentication window.

Submitting an erroneous entry will be visualized by the red colour of the input fields (Fig. 47).

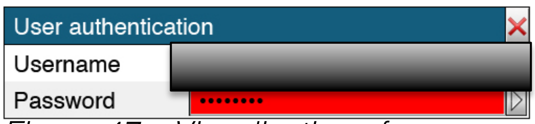


Figure 47 – Visualization of an erroneous entry.

8.6.8. General PWS control

The menu allows the user to start or stop the entire plant by clicking 'General PWS control' in the menu. This will result in a small pop up window at the top left of the screen (Fig. 48). To start the PWS users can click on the 'Start button'. Hiding the general control functionality behind the menu button prevents an accidental press of the stop (or start) button.

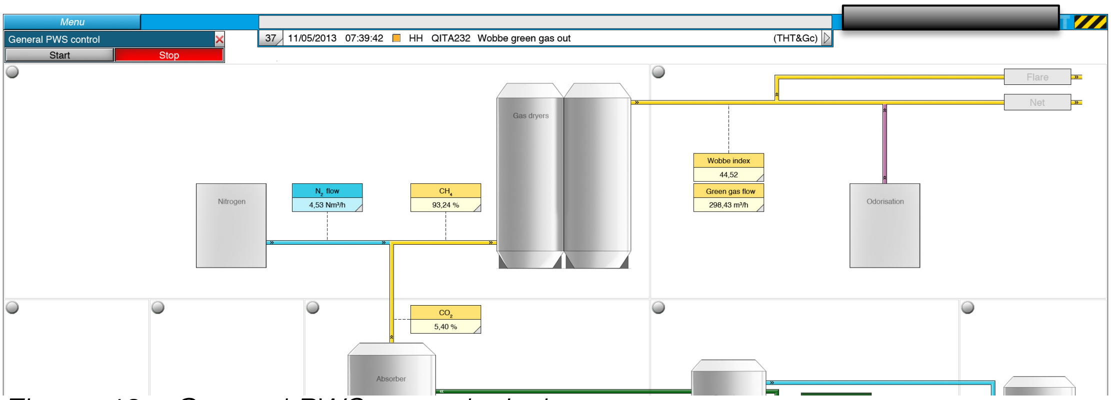


Figure 48 – General PWS control window.

If there is any reason why the PWS cannot be started the General PWS control window will expand and give a description of the issue (Fig. 49).

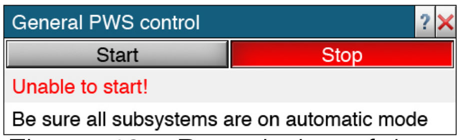


Figure 49 – Description of the reason the PWS cannot start.

8.6.9. Print screen

The last feature of the user interface gives the user the opportunity to take a snap shot of the current screen. The 'Print screen' window will be shown at the top left of the screen (Fig. 50). It is recommended to store the file at a fixed location on the server. The filename is split in to a fixed and a variable part. The fixed part is constructed of the current date, time and user. This is important when deviations between two or more different points in time have to be analysed. The variable part gives users the option to add notes to the title of the print screen file. The print screen functionality will assist users in analysing and communicating specific PWS data.

8.6.10. Quit

Used to exit the entire user interface.

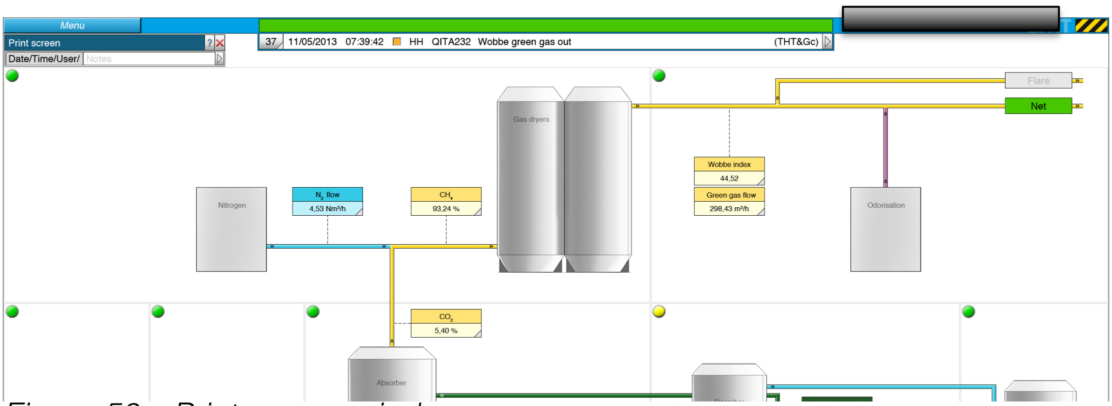


Figure 50 – Print screen window.

9. Verification of requirements

Not only during the design process but most certainly at the end of it, it is important to evaluate the concept using the requirements of section 6.1. In all honesty the author of this report will determine whether a requirement is met by the design.

Keeping the current user interfaces in mind, the recommendation for redesign has been discussed within DMT with both experienced users (engineers) as inexperienced users. Overall the design meets the requirements pretty well. It is believed that implementing this design will significantly decrease the difficulty of understanding the PWS plant and performing a user's tasks. This will improve the overall performance of the user and – maybe even more important – the upgrading process of the plant.

The user interface is understandable, usable and very safe by the implementation of user levels that reflects in the accessibility of all kind of interface features.

The following section evaluates the design requirements that are partially or not met. An evaluation of all requirements can be found in Appendix A.

9.1 Functional requirements evaluation

1. *The interface should support a way of authentication.*
   a. Each group of users will have a different level of interface complexity.
      - The user interface should display the current level of complexity.

      Requirement partially met, alternative provided: each user will have their own username and password linked to a certain user level. The current user is always visible in the top of the screen. Using the interface when another user is logged in should never happen. See section 8.1.4.

2. *The interface should ease the user by decreasing the difficulty of reading and understanding the current state of the PWS.*
   c. The user interface should display relevant data.
      - The amount of presented data is dependant of the level of complexity.

      Requirement not met, alternative provided: PID settings have been implemented in the corresponding parameter providing a clearer view. It was not needed to adapt the amount of presented data to the different user levels.

   e. The user interface should filter accessible trending modules.
      - Accessible trending modules are dependant of the level of complexity.

      Requirement not met: trending modules are not part of the redesign process.

4. *The interface should improve the PWS uptime by decreasing the amount of critical errors and help users solve occurred errors more efficient in a shorter amount of time.*
   e. Alarms should help the user solving the problem.
      - Alarm notifications should inform the user with important information concerning the alarm.

      Requirement not met: the alarm information fully informs the user and creates a link between to the location of the alarm in the interface representation. The alarm is clearly shown in the interface schematic representation but does not tell a user what to do.

h. The user interface should contain DMT contact information.
   Requirement not met: implementing would require minimal effort.
   - The user interface should give an option to visualize DMT's contact information for required service.

   Requirement not met: implementing would require minimal effort.

8. *The user interface should fit within the stated hardware restrictions.*
   a. The user interface should work on tablet or smartphone.
   Requirement partially met: the positioning of the framework, parts and other elements contribute to easier control with a tablet or smartphone. The user interface is not optimized for mobile devices.
   - Visualisation of the interface on the computer monitor should also fit tablets and smartphones.

   Requirement partially met: the aspect ratio of the redesign (16:10) suits most tablets. Smartphones resolutions vary too much to make a statement about.

10. Comparison

The following part compares the redesign with respect to the current user interface. It highlights the most important improvements and the positive effect for the user.

10.1. General UI improvements

1. Realistic parts and components
   a. Vessels differ in size to clarify differences between them.
   b. All components – vessels, valves, compressors and motors – are presented in 2d with a 3d look to give each part a certain value and indicate the importance.

   The current user interface is very flat (2d) where PWS components were pushed backwards by the large amount of frames, buttons and pipelines.

2. Aligning UI elements
   a. All components are aligned to a grid. PWS parts are positioned at the same height, pipes have a fixed distance from each other and never cross each other. This creates a very clean view and improves the general understanding of the user interface.
   b. The menu button is positioned at the top left. This position will be recognized, users are used to this position for a menu in other computer software.
   c. Navigation buttons can be found at the bottom. Switching between different views/windows with the navigation buttons works the same as switching between different programs or windows in other computer software.

   Aligning UI elements ensures a clean and understandable representation. The current interface has its parts and pipes positioned random, creating undesirable chaos and noise on the screen.

   The general controls of current user interfaces all differ from each other.

3. Process orientation and subsystem distribution.
   a. The interface is read from left to right and from bottom to top, making the user interface easy to read. Reading from left to right is natural for users and the flow of a gas naturally goes upwards.
   b. Related parts are distributed evenly among the subsystems to prevent one being overfull and prevent blank screens.

   Orientation of the current user interface is very random. Operators have a hard time understanding the flow of the process.

4. Directional arrows
   a. At the start and end of each pipelines two small arrows indicate the direction of the flow within the concerning pipe.

   It is never questionable whether a pipe enters or leaves a PWS part. Users have to search for the direction of the flow in the current user interface.

5. Act like expected
   a. Whenever parameter settings or settings of a valve are requested a user can simply click the parameter frame or the part itself.
   b. Buttons present themselves as clickable or expandable.

Clicking a parameter frame of part will result in a pop up window at the source itself. The pop up is positioned at the bottom right side of the concerning part. Currently pop ups are not positioned consistently or users even have to take multiple actions to show e.g. the PID settings.

This pop up positioning has effect on the placement of other parts like the subsystem state indications. These indications are positioned at the top left. If they were positioned at the top right, some pop up windows would fall outside the screen.

10.2. Job assistance improvements

1. User levels
   a. The interface handles 5 different user levels following from the parameter analysis. Each level differs in the amount of restrictions users have to control all settings and features.

   The current SCADA systems do not restrict the users enough, still giving them the possibility to change settings even if they have too little process knowledge in order to make a deliberate decision.

2. Flare/Net, State bar and subsystem state indication
   a. The flare/net indication informs the user whether the produced gas is being burned or sent through the gas network.
   b. The state bar is always visible and is located at the top of the screen.
   c. The subsystem state bubbles are located at the left corner of each subsystem screen and at the top left of each subsystem at the overview page.

   The state bar and subsystem state indication keeps the user informed at all times. Together with the alarm bar the user is always informed about the current state of the PWS process. The current user interface did not support any general state visualisation at all. Users had to check multiple parameters in order to obtain this kind of information.

3. Alarm links
   a. Users can easily locate the exact position of an alarm by clicking the ‘go-to’ button at the end of the alarm notification. The alarm can easily be located by looking for the red parameter frame (if the alarm is urgent).

   Users often had a hard time finding the exact location of an alarm in the current user interfaces.

4. General state and subsystem state indication and control.
   a. Users van easily read the general state of the entire process at the top of the screen. This indication is visible regardless of the current window.
   b. The state of an individual subsystem is visualized on the overview page as well as the subsystem pages.
   c. Subsystem indications can be clicked to change the control settings of an entire subsystem. This window is hidden by default to keep the screen as clean as possible.

   Current UI’s do not inform the user about the general state. Users have to check alarms and parameters in order to acquire this information. The same applies to the state of subsystems.

Control settings for a subsystem were available but always visible and positioned at random.

5. Quick stop
    a. The user interface provides a quick stop button. In case of emergency users are able to stop the entire plant with this feature. Accidental presses of this button are prevented.

    Current user interfaces had no way to stop the entire plant in a short amount of time.

6. Logging and export data.
    a. The user interface automatically saves changes that are made by a user. The log saves all relevant data and the user who made the change. There is also room to leave a note at every single change.
    b. The data log supports an export function.

    Current user interfaces do not keep track of changes within the interface. Logging changes and giving the possibility to export the log informs users, reduces confusion and improves the communication of the process data.

7. Parameter list & user rights
    a. The alarm and PID settings of all parameters are put in a list. A useful tool in the overall control, especially for expert users.
    b. Users with the safety level (highest user level) are able to change the required user level users need in order to change a specific alarm or PID setting.

    Parameter lists were usually saved in an excel file but were not kept within the user interface itself. Implementing it in the user interface will prevent confusion.

8. Print screen, chat function and data log notes.
    a. The print screen function captures the current window. The file is automatically titled with the current date, time and user.
    b. In the chat screen users can write messages to improve communication. If there are unread messages the menu button will show a notification.
    c. In the data log screen users can leave a note to explain why a certain change has been made. A useful addition when possible alarms concerning this change in the future might occur and troubleshooting is required.

    Current user interfaces lacked both features. Both of them improving communication within and outside of the interface. Possible errors could be captured and sent – for example – by email to a colleague.

9. Filtering results & pairing data
    a. The windows of all features give the possibility to filter the data shown. Filters that could be applied are dependant of the feature shown.
    b. Data is always shown in the same order: Date – Time, Severity – Type and Tag – Description – Subsystem.

    Current SCADA systems did not give the possibility to filter data or provided absolutely no overview of different types of data. Data presented was not in a fixed order.

11. Conclusion

This report contains a recommendation for the design of the future PWS SCADA user interface. This recommendation is supported by a concept in which all recommendations are implemented.

The future interface supports job assistance features to not only ease the user but also improve the overall performance of their task execution. One of the most important implemented features is the authentication of users. Each user is coupled to one of the five user levels that determine the amount of possibilities within the user interface. Users have to authenticate themselves by entering a username and password in order to gain access to the interface settings and features. This feature ensures safety and prevents undesirable errors from happening.

Checking the general state of the entire process or even individual subsystems has become very easy. The general state is always visible regardless of which window is shown. The overview page shows all subsystem states while a subsystem only shows its own state. The visualisation of these states and the alarm bar notification keep the user informed at all times.

The data log the system provides keep track of all changes that are made by a user. It shows all parameter information as well as the factory, precious and current value. A very useful addition to the data log is that it states the initials of the user who made the change and leaves room for a note. Users can enter why a certain change has been made. These notes prevent confusion and helps with possible troubleshooting of an alarm concerning this parameter in the future.

The basic representation of the PWS plant is greatly improved and the amount of parameters, buttons, navigation buttons, and many more elements are as minimal as possible. Compared to the current user interface the redesign provides a clean and understandable view with a logical orientation (from left to right). The colours used for the pipelines and parameter frames are derived from the NEN 3050 standard. Using this standard for every future PWS interface creates recognition and prevents confusion. Parameter frames concerning a gas – yellow following the NEN 3050 standard – are exactly the same colour, making the overall understanding of the process even easier.

The redesign has been made conform the usability heuristics provided by Nielsen (Nielsen & Mack, 1994).

The recommendation has already been partly used in the user interface of DMT's new plant commissioned by [redacted] ([redacted]), showing great improvement to the previous interface.

12. Recommendations

The following recommendations can be made to improve the future interface even more:

- The alarm bar shows the amount of outstanding alarms but does not show the amount of new alarms. Implementing the number of new alarms since the last time the alarms were checked improves the overall performance. The visualization of the amount of new alarms is shown in figure 51. In this example there are 21 outstanding alarms in total of which 16 are new.

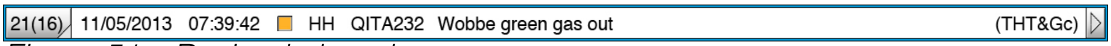


Figure 51 – Revised alarm bar.

- The data log could be improved by integrating a go-to button. This could be useful whenever a user notifies a wrong input value and needs to change the concerning value. The go-to button will create a link between the data log page and the exact location of the parameter in the user interface. Clicking the go-to button will also automatically show the expanded parameter frame. The go-to button integrated in the data log is shown in figure 52.

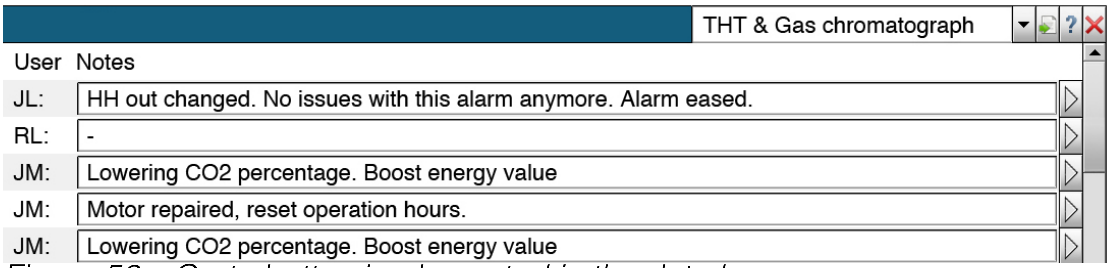


Figure 52 – Go-to button implemented in the data log.

- The simulation mode should show both simulated as well as the real value of the parameter. When a user decides to simulate a parameter an extra bar showing this value should pop up. Figure 53 shows an example of this solution.

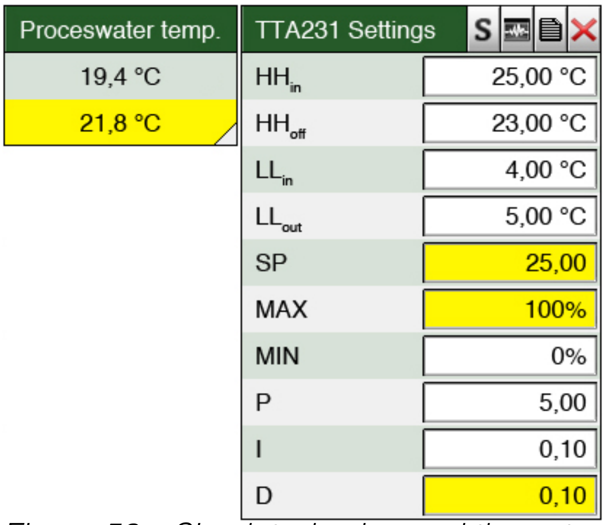


Figure 53 – Simulated value and the actual value are shown.

- To keep the control of the plant as easy and accessible as possible – especially for the operators with basic level – some easy control features could be added to the overview page. The plus and minus buttons that are located at the top of the expanded parameter frame ease the user in making minor adjustments to the upgrading process. Pressing the plus button will result in an increase of the parameter without users having to change single PID settings. The buttons are shown in figure 54.

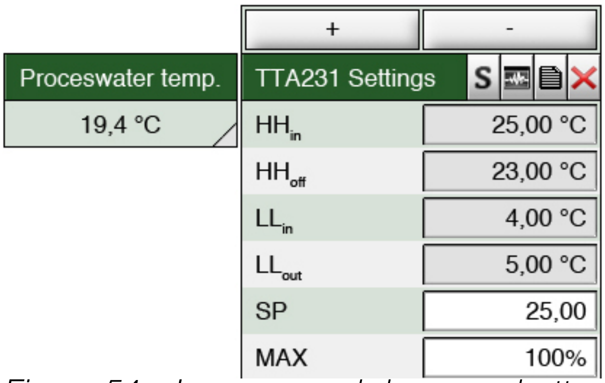


Figure 54 – Increase and decrease buttons.

- The user interface – hopefully – does not require a lot of explanation. At this point in time the user interface does not offer any help functionality. The help feature (pretty much) each window contains requires further research.

- Valves, compressors and motors do not clearly state that they are clickable. Implementing the expand icon is an unpleasant solution. To visualize those parts as clickable by – for example – a mouse-over function further research is required.

- The indication of the current user (see section 8.1.4.) does not include the associated user level. Providing this information could be useful.

- The benefits of replacing the filter feature with search functionality will require further research. A possible combination is not excluded as long it improves the ease of use.

- The trending module could definitely be improved in the future user interface.

- A slight improvement to some of the visualisation of the subsystem filter would be to show ‘All subsystems’ instead of ‘All alarms’ to clarify the effect of the filter.

- DMT contact information should be included in the interface.

- The user interface should be translated to be workable on a tablet or smartphone. This will require further research.

- Alarm notifications don’t offer a concrete solution to the problem. This information is very specific and different for every single alarm. Researching the exact solution will require a lot of time and specific knowledge and the question is whether it is worth it the effort.

13. List of sources

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Appendix A – Functional requirements evaluation

1. *The interface should support a way of authentication.*
    a. Each group of users will have a different level of interface complexity.
    Requirement met: see section 7.4.5.
    - The user interface should display the current level of complexity.

    Requirement partially met, alternative provided: each user will have their own username and password linked to a certain user level. The current user is always visible in the top of the screen. Using the interface when another user is logged in should never happen. See section 8.1.4.

    b. Each group of users will have different control rights in the interface.
    Requirement met: see section 7.4.5. ; 8.3.3. ; 8.3.5. ; 8.6.2. and 8.6.5.

2. *The interface should ease the user by decreasing the difficulty of reading and understanding the current state of the PWS.*
    a. The schematic representation of the PWS should be understandable.
    Requirement met: see section 8.4. and 8.5.
    - Schematic representation should only display relevant PWS parts, dependant on the level of complexity and the data the users require to see.

    Requirement met: see section 8.4. and 8.5.
    - Schematic representation should be logically positioned.

    Requirement met: see section 8.4. and 8.5.

    b. The user interface should display the current general state of the PWS.
    Requirement met: see section 8.1.2.

    c. The user interface should display relevant data.
    Requirement met: see section 8.4.
    - The amount of presented data is dependant of the level of complexity.

    Requirement not met, alternative provided: PID settings have been implemented in the corresponding parameter providing a clearer view. It was not needed to adapt the amount of presented data to the different user levels.

    d. The user interface should filter accessible settings of data.
    Requirement met: see section 7.4.5. ; 8.3.3. ; 8.3.5. ; 8.6.2. and 8.6.5.
    - The amount of accessible settings is dependant of the level of complexity.

    Requirement met: see section 7.4.5. ; 8.3.3. ; 8.3.5. ; 8.6.2. and 8.6.5.

    e. The user interface should filter accessible trending modules.
    - Accessible trending modules are dependant of the level of complexity.

    Requirement not met: trending modules are not part of the redesign process.

3. *The user interface should support job assistance features that decrease the difficulty of controlling the PWS.*
    a. Interface navigation elements should speak for themselves.
    Requirement met: see section 8.1.1. and 8.1.7.
    - Clickable elements should present themselves as clickable.

    Requirement met: all buttons represent themselves as clickable or indicate they are selected.
    - The user interface should have clear start/stop buttons.

    Requirement met: see section 8.1.6. and 8.6.8.
    - Active and/or inactive interface elements should clearly present their current state.

    Requirement met: see section 8.1.1. ; 8.1.7. and 8.3.3.

b. Navigation between different layers of the user interface should require minimal amount of actions.
   Requirement met: see section 8.1.7.
c. Changing values should require minimal amount of actions.
   Requirement met: see section 8.3.5. and 8.6.5.
d. Pop-up windows should not obstruct the rest of the interface.
   Requirement met: pop up frames will have a default location but can be moved.
   - The interface should support multiple pop-up windows.

   Requirement met:
   - Pop-up windows should be moveable or have a fixed position in the interface.

   Requirement met: pop up frames will have a default location but can be moved.
e. The interface should offer an option to take a snap shot of the current presented view.
   Requirement met: see section 8.6.9.

4. *The interface should improve the PWS uptime by decreasing the amount of critical errors and help users solve occurred errors more efficient in a shorter amount of time.*
   a. The user interface should have a clear way of notifying an alarm.
      Requirement met: see section 8.1.3.
   b. The user interface should state the severity of the alarm.
      Requirement met: see section 8.1.3. and 8.6.1.
   c. The user interface should show the amount of outstanding alarms.
      Requirement met: see section 8.1.3.
   d. The user interface should show the position of the occurring alarm in the schematic representation of the PWS.
      Requirement met: see section 8.1.3.
      - Alarm notifications should create a link between the notification and the position of this alarm in the schematic representation of the PWS.

      Requirement met: see section 8.1.3.
   e. Alarms should help the user solving the problem.
      - Alarm notifications should inform the user with important information concerning the alarm.

      Requirement not met: the alarm information fully informs the user and creates a link between to the location of the alarm in the interface representation. The alarm is clearly shown in the interface schematic representation but does not tell a user what to do.
   f. The system should automatically log changes of data. Corresponding tag, date and time, user who made the change and attached notes will be logged with it.
      Requirement met: see section 8.5.4.
      - The user interface should present a way to visualize these data logs.

      Requirement met: see section 8.5.4.
   g. The system should support a simulation modus that could be turned on when a test is being done.
      Requirement met: see section 8.3.5.
      - The user interface should give the option for simulation mode.

      Requirement met: see section 8.3.5.
      - The user interface should communicate whether or not simulation mode is active.

      Requirement met: see section 8.3.5.
   h. The user interface should contain DMT contact information.
      Requirement not met: implementing would require minimal effort.

- The user interface should give an option to visualize DMT's contact information for required service.

  Requirement not met: implementing would require minimal effort.

5. *The user interface should match DMT's company image.*
   a. Interface representation should match DMT's colour composition.
      Requirement met: see section 8.1.5.
   b. The interface should contain a DMT logo.
      Requirement met: see section 8.1.5.

6. *The user interface should fit within the stated hardware restrictions.*
   a. The user interface should work with mouse and keyboard.
      Requirement met: see section 7.2.
   b. The user interface should be designed conform the stated screen resolution.
      Requirement met: see section 8.1.
   c. The user interface should work on tablet or smartphone.
      Requirement partially met: the positioning of the framework, parts and other elements contribute to easier control with a tablet or smartphone. The user interface is not optimized for mobile devices.
      - Visualisation of the interface on the computer monitor should also fit tablets and smartphones.

      Requirement partially met: the aspect ratio of the redesign (16:10) suits most tablets. Smartphones resolutions vary too much to make a statement about.
   d. The SCADA system should support job assistance features that could easily import/export data and communicate these over the internet.
      Requirement met: see section 8.6.4. and 8.6.9.

7. *The user interface should present PWS parts, tags, connections and other elements following understandable (international) standards.*
   a. PWS parts should be standardized for future PWS SCADA interfaces.
      Requirement met: see section 8.3.1. – 8.3.4.
   b. Tag names, colouring and positioning should be applied in a consistent way.
      Requirement met: see section 7. and 8.
   c. Line colouring, positioning and direction should be applied in a consistent way.
      Requirement met: see section 8.3.6. ; 8.4. and 8.5.

Appendix B – Large user interface images

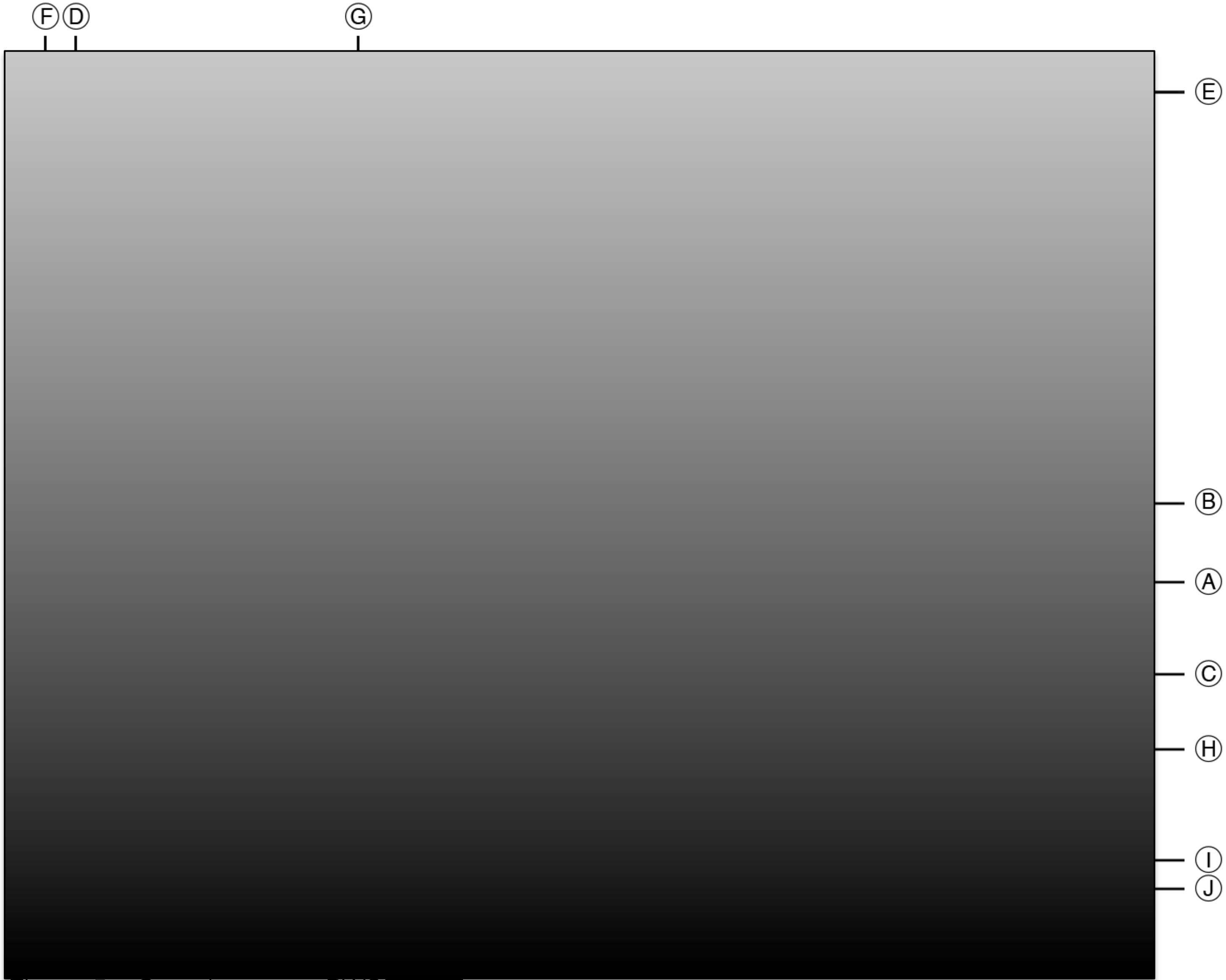


Figure 5 – Overview page PWS [redacted].

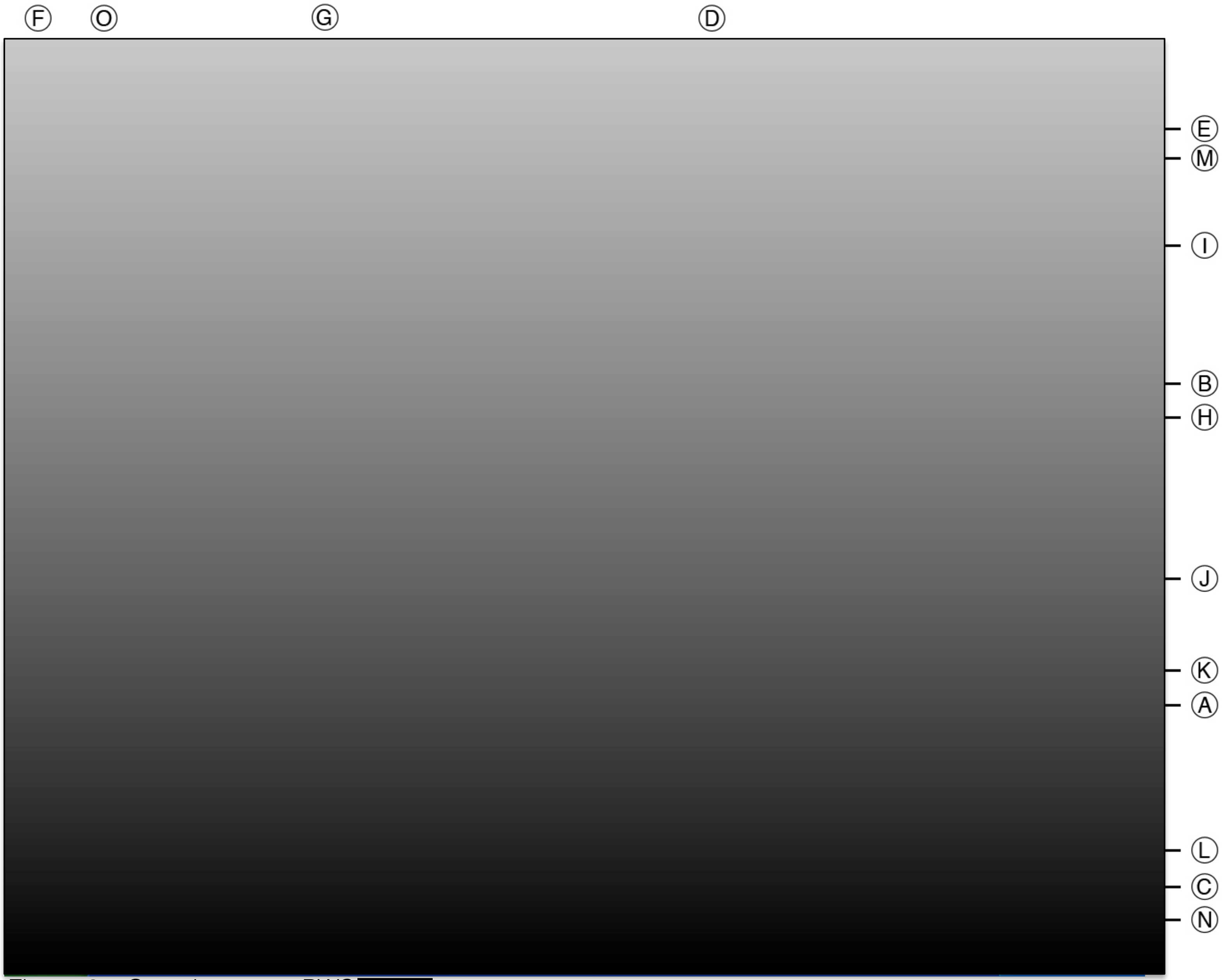


Figure 6 – Overview page PWS [redacted].

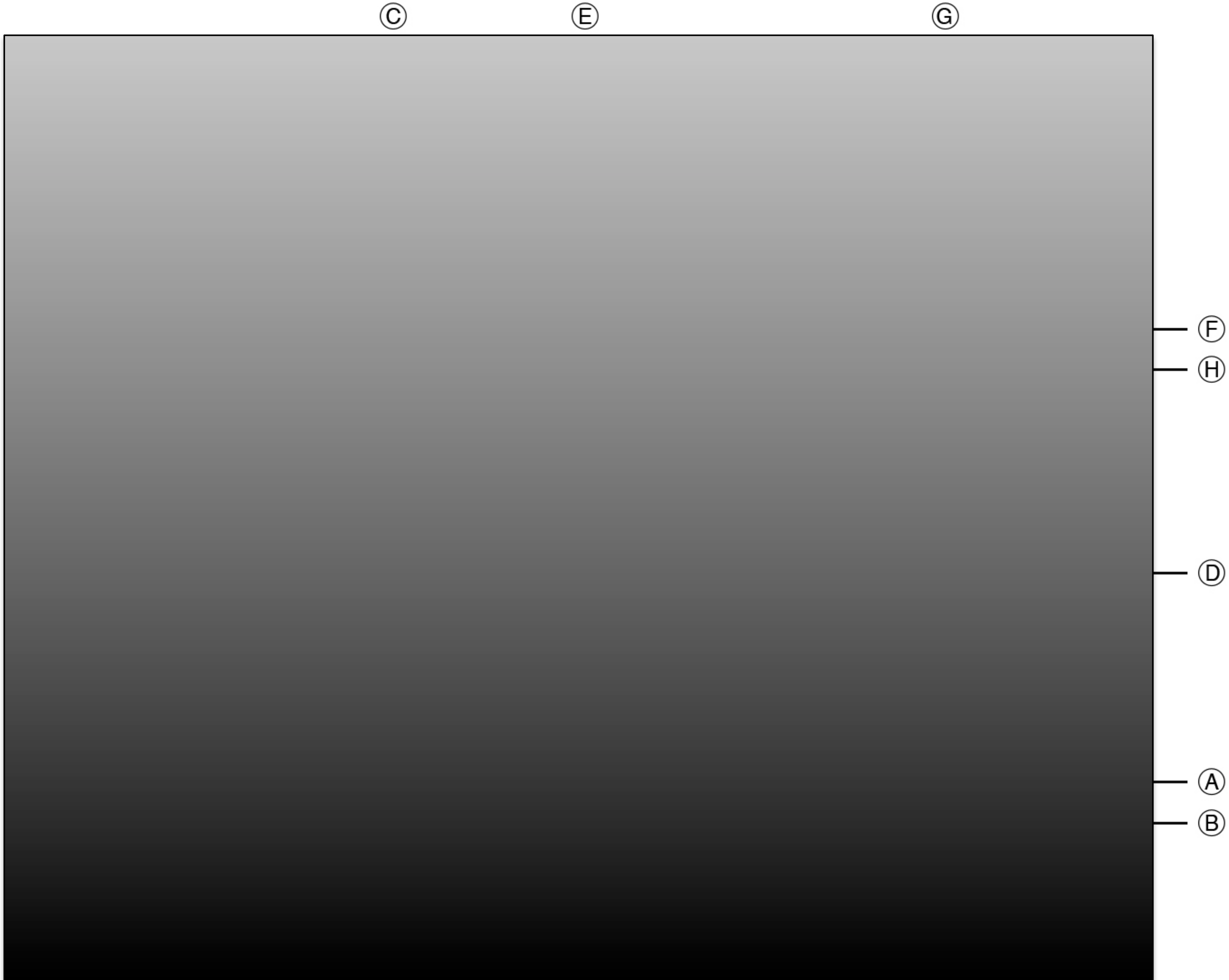


Figure 7 – Water circulation page PWS [redacted].

Figure 8 – Absorption page PWS [redacted].

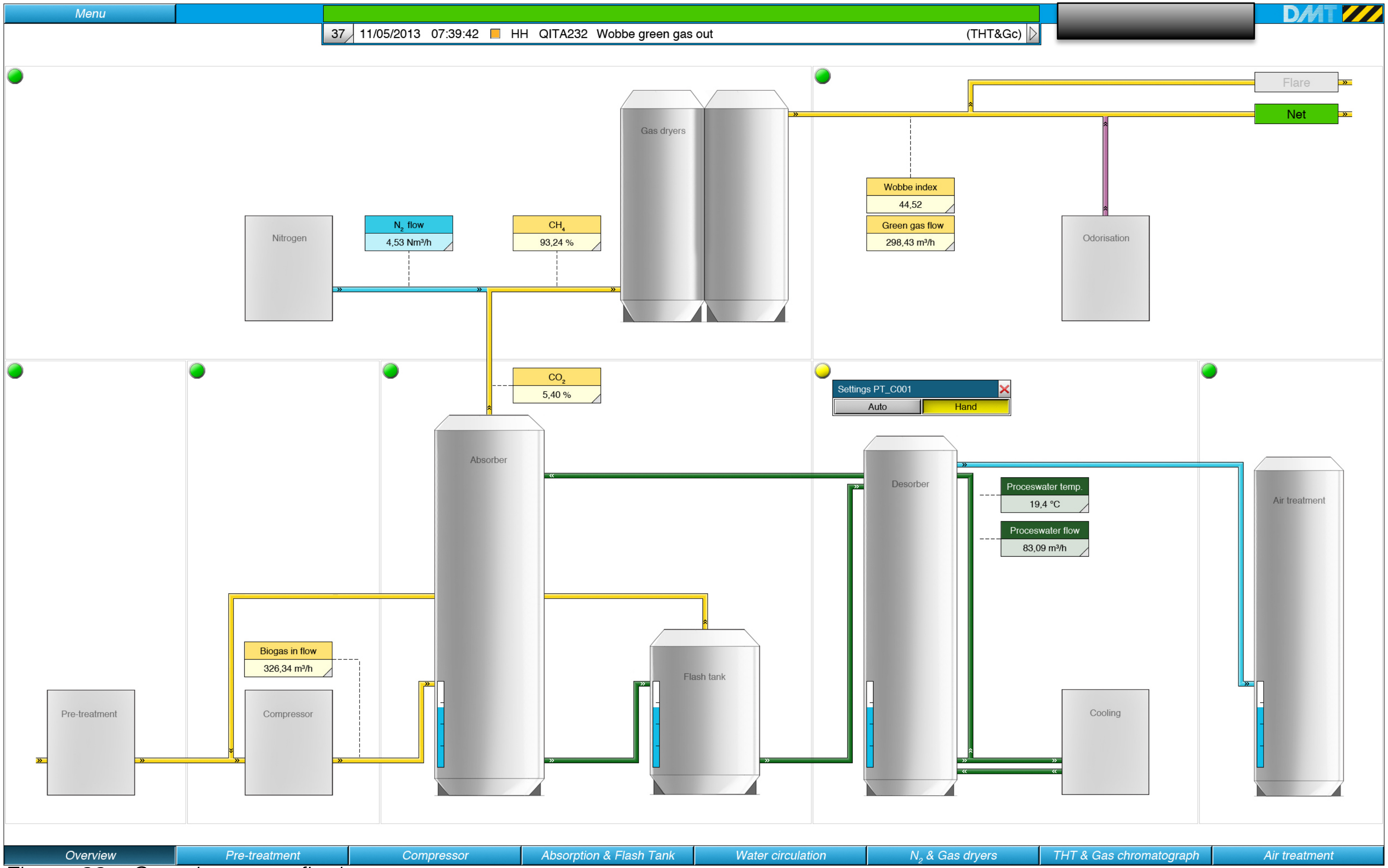


Figure 33 – Overview page final concept.

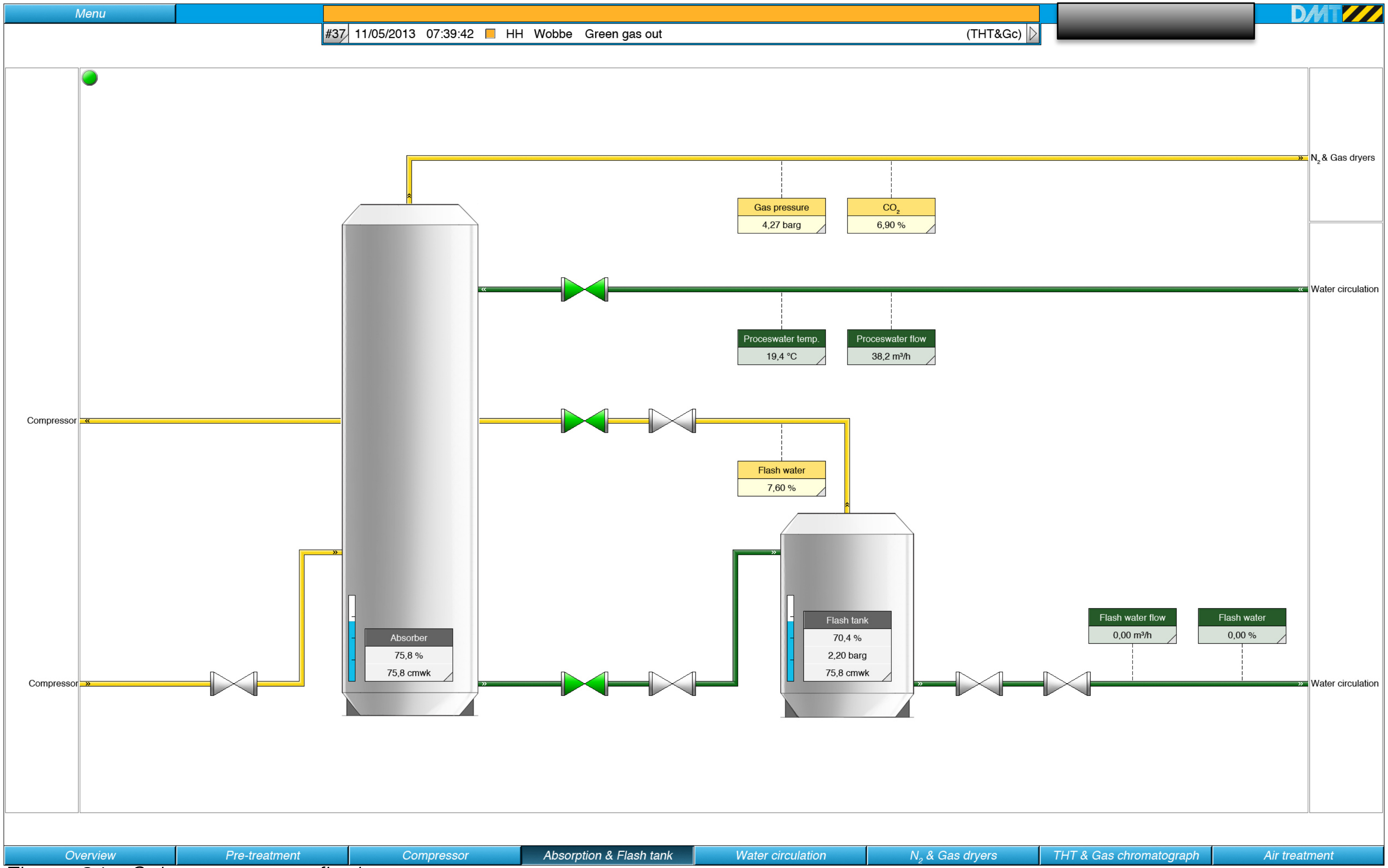


Figure 34 – Subsystem page final concept.

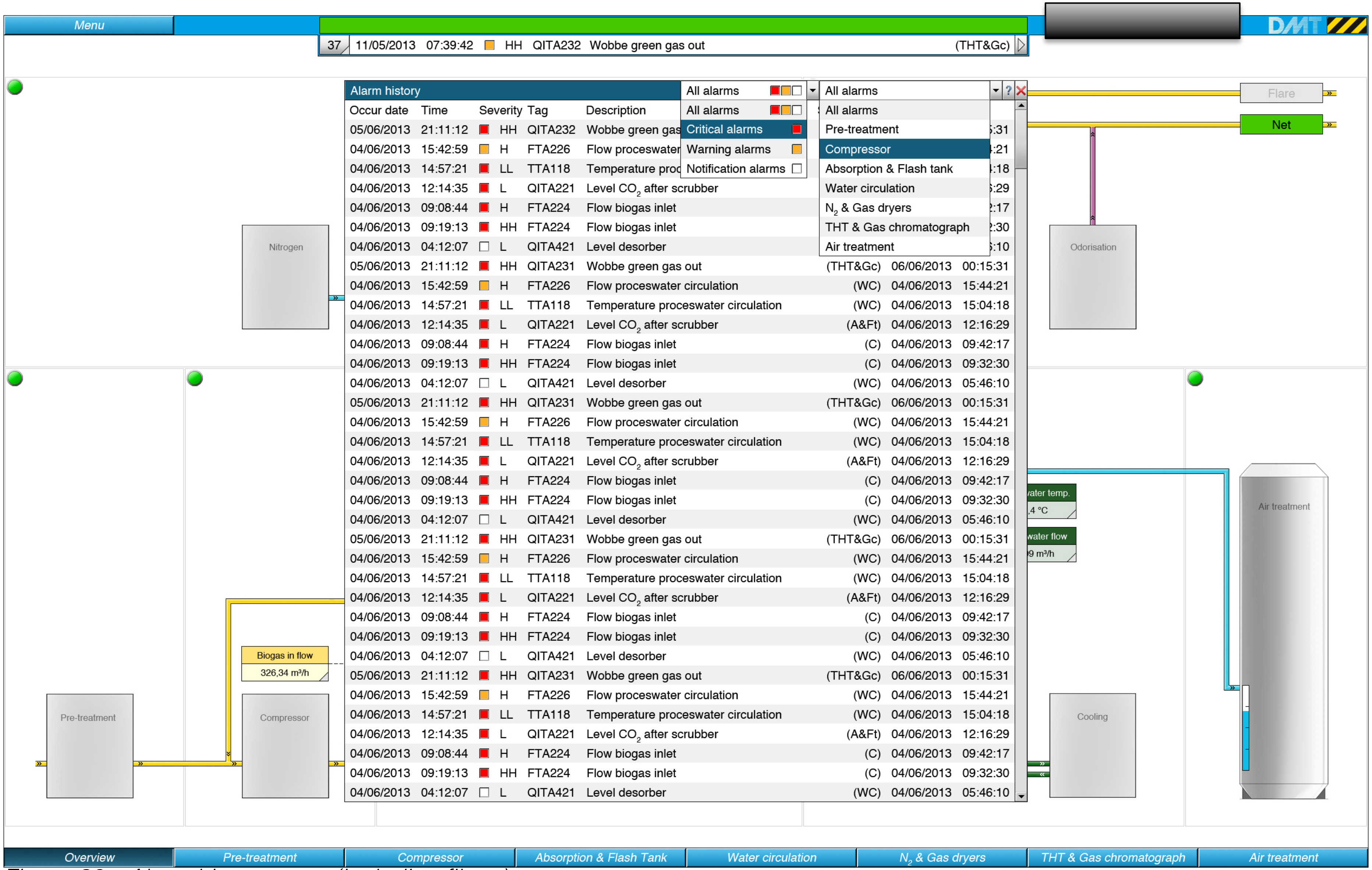


Figure 36 – Alarm history page (including filters).

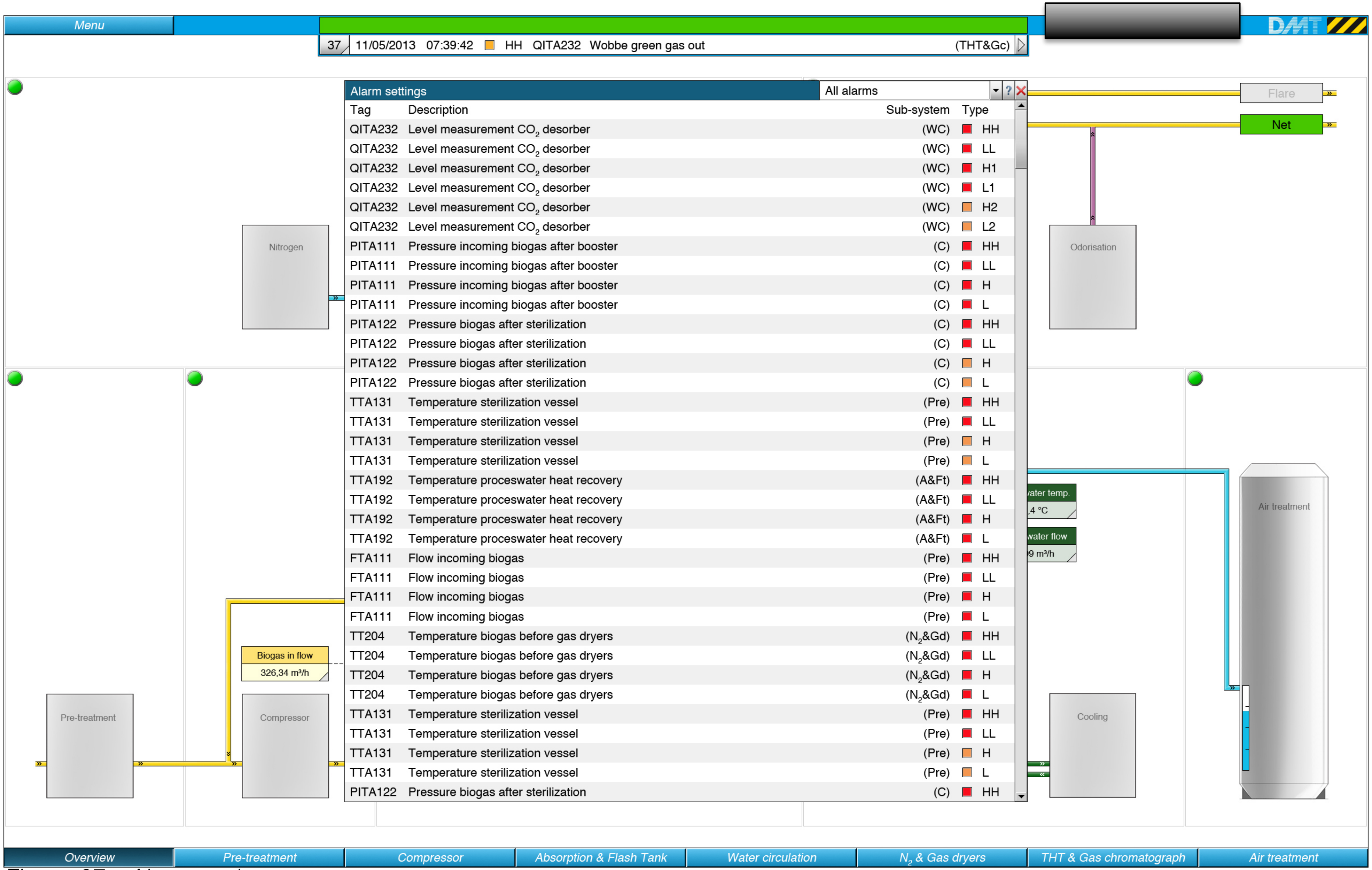
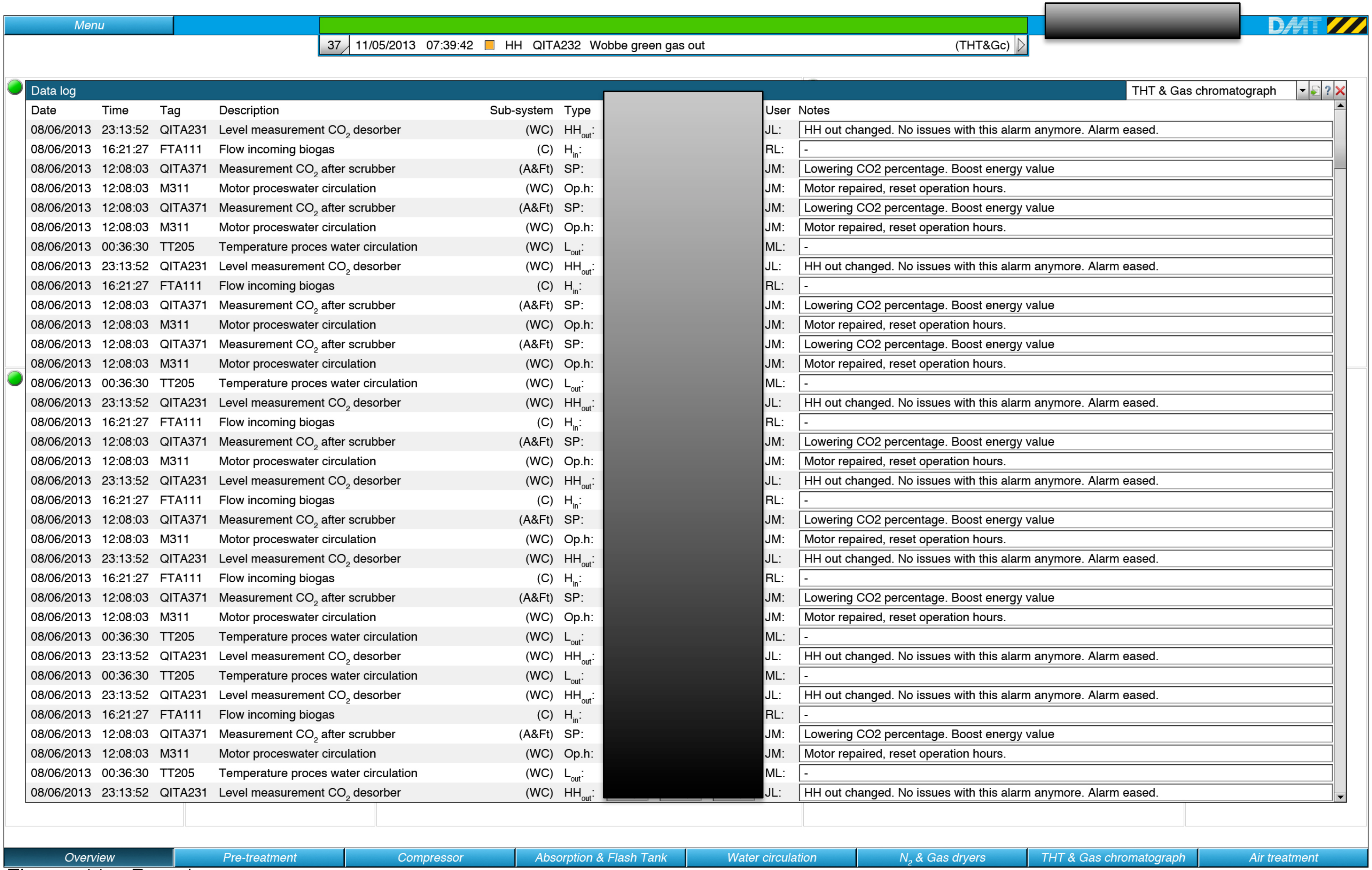


Figure 37 – Alarm settings page.



Date	Time	Tag	Description	Sub-system	Type	[redacted]	User	Notes
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	00:36:30	TT205	Temperature proces water circulation	(WC)	L_{out}:		ML:	-
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	00:36:30	TT205	Temperature proces water circulation	(WC)	L_{out}:		ML:	-
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	00:36:30	TT205	Temperature proces water circulation	(WC)	L_{out}:		ML:	-
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	00:36:30	TT205	Temperature proces water circulation	(WC)	L_{out}:		ML:	-
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.
08/06/2013	16:21:27	FTA111	Flow incoming biogas	(C)	H_{in}:		RL:	-
08/06/2013	12:08:03	QITA371	Measurement CO_2 after scrubber	(A&Ft)	SP:		JM:	Lowering CO2 percentage. Boost energy value
08/06/2013	12:08:03	M311	Motor processwater circulation	(WC)	Op.h:		JM:	Motor repaired, reset operation hours.
08/06/2013	00:36:30	TT205	Temperature proces water circulation	(WC)	L_{out}:		ML:	-
08/06/2013	23:13:52	QITA231	Level measurement CO_2 desorber	(WC)	HH_{out}:		JL:	HH out changed. No issues with this alarm anymore. Alarm eased.

Figure 41 – Data log page.

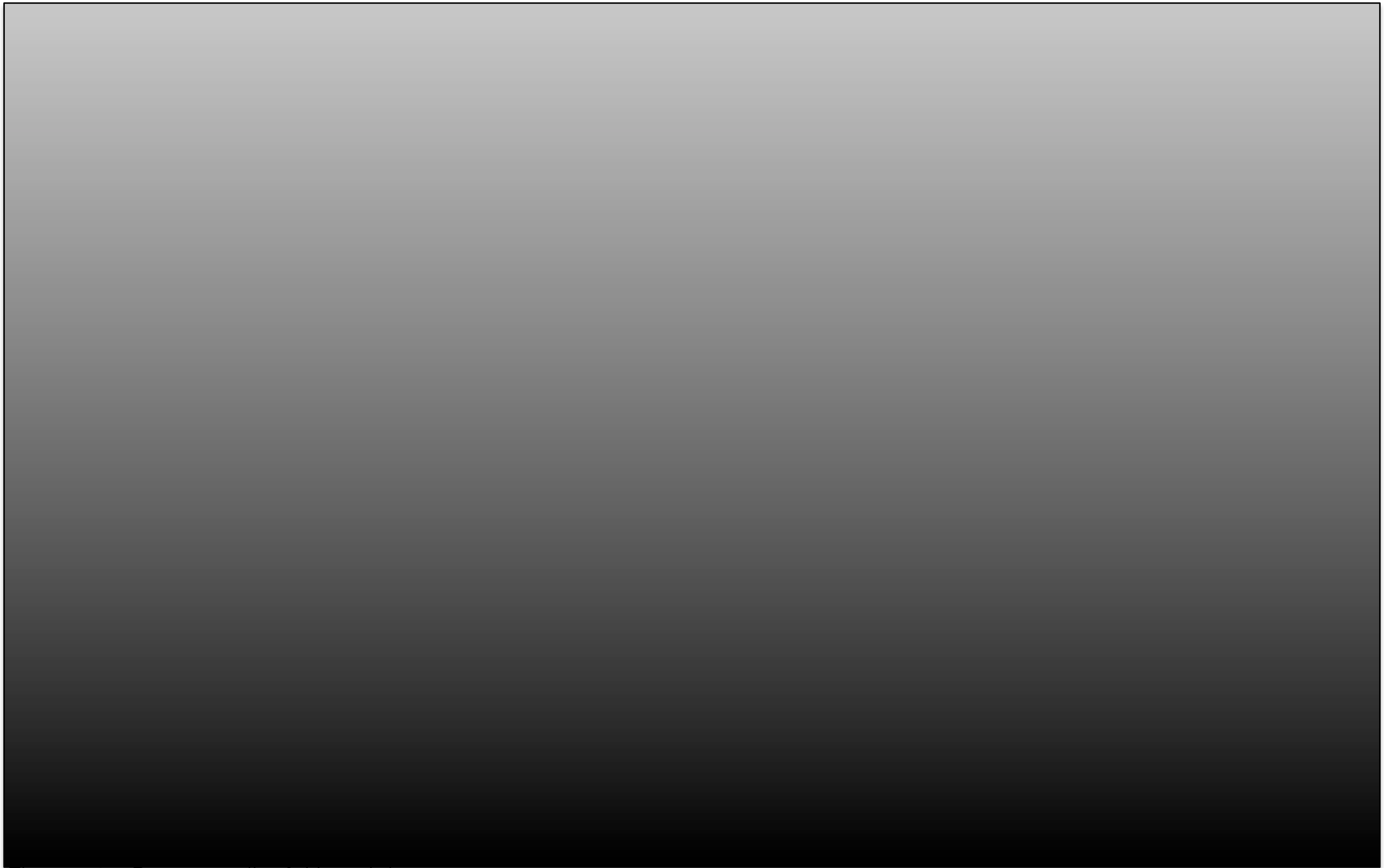


Figure 43 – Parameter list & User rights page.

Appendix C – Example of the design process

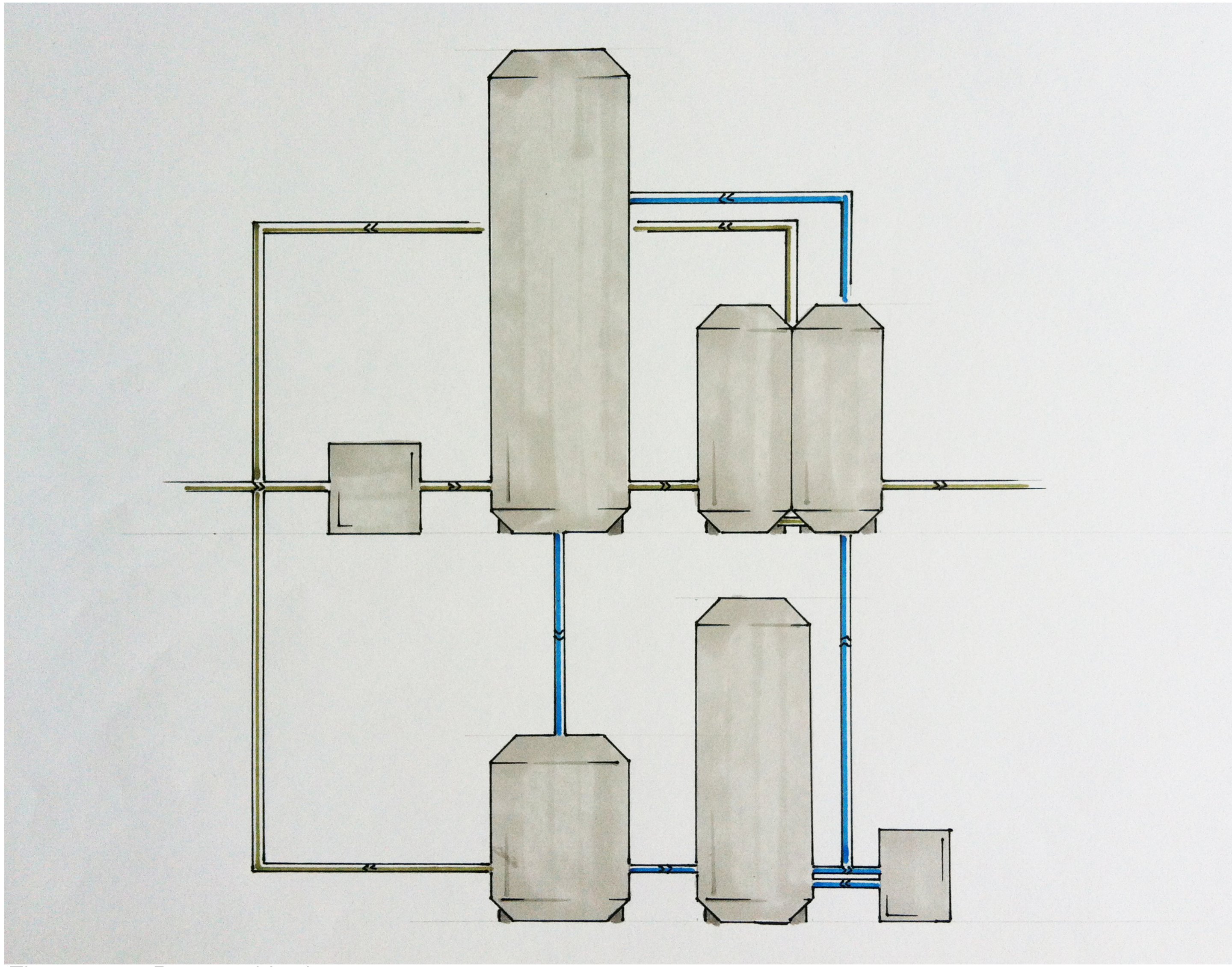


Figure 55 – Part positioning concept 1.

This concept was not chosen because the attachments of the pipelines were not ideal. The gas flow from the Flash Tank to the Compressor leaves the flash tank at the left side. The idea is to keep the input at the left side and the output at the right side of a part.

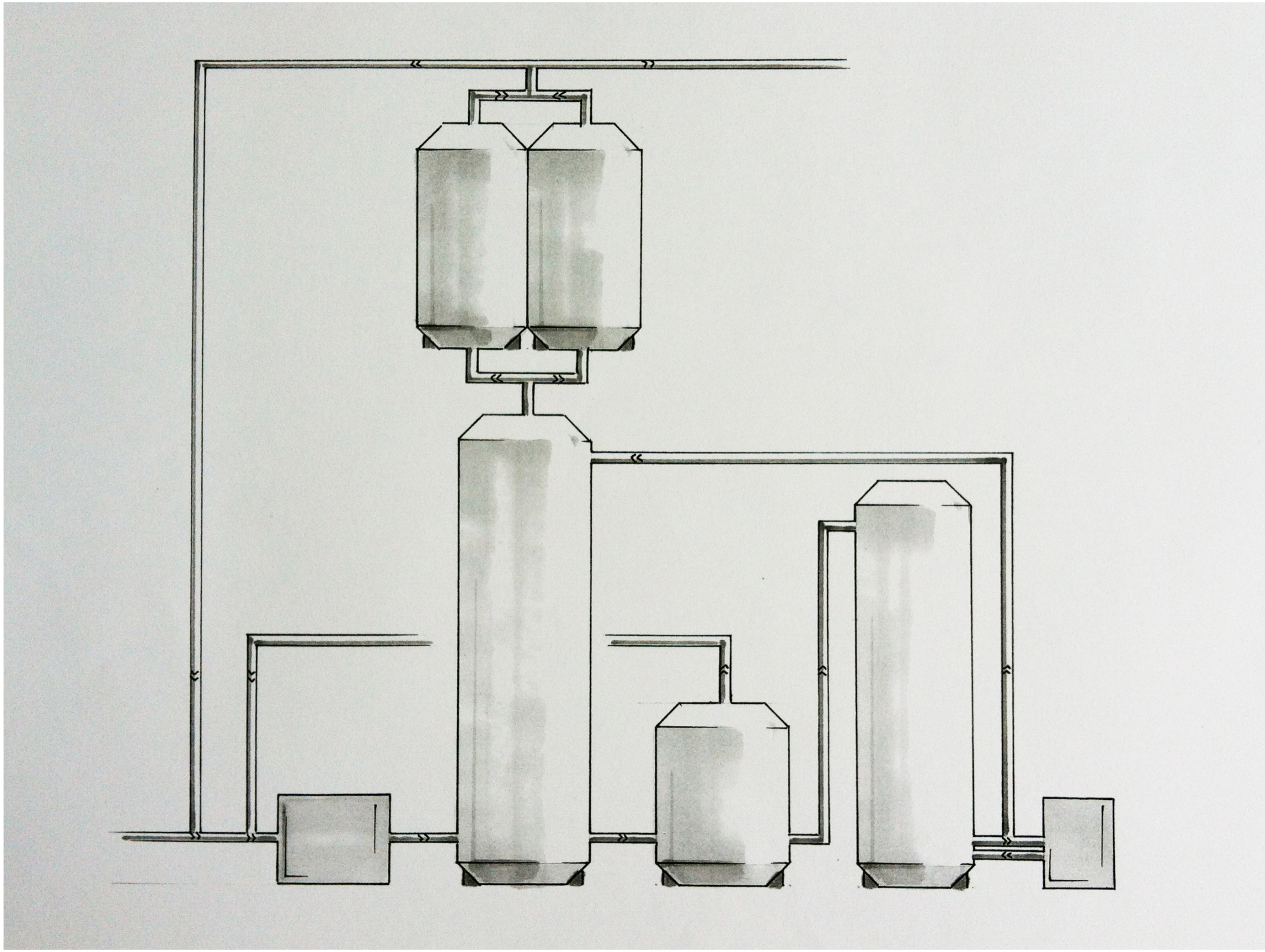


Figure 56 – Part positioning concept 2.

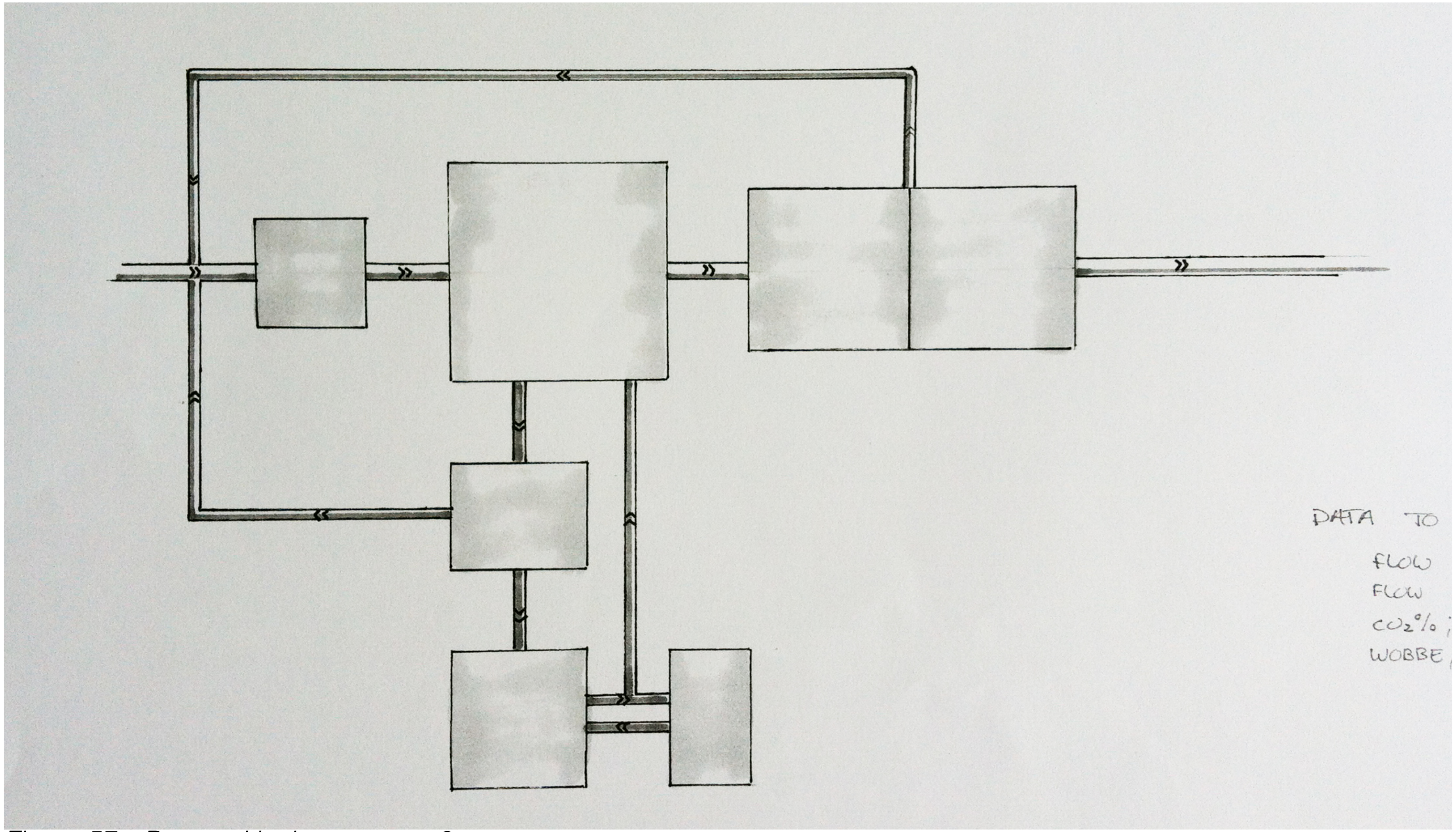


Figure 57 – Part positioning concept 3.

This concept of part positioning is made in top-down view. This solution is not ideal because it is hard to create recognition of the parts for a user. A concept that uses the side view can easily show the differences between parts. For example: the flash tank and the desorber by the difference in height.

Figure 58 – Alarm settings design process 1.

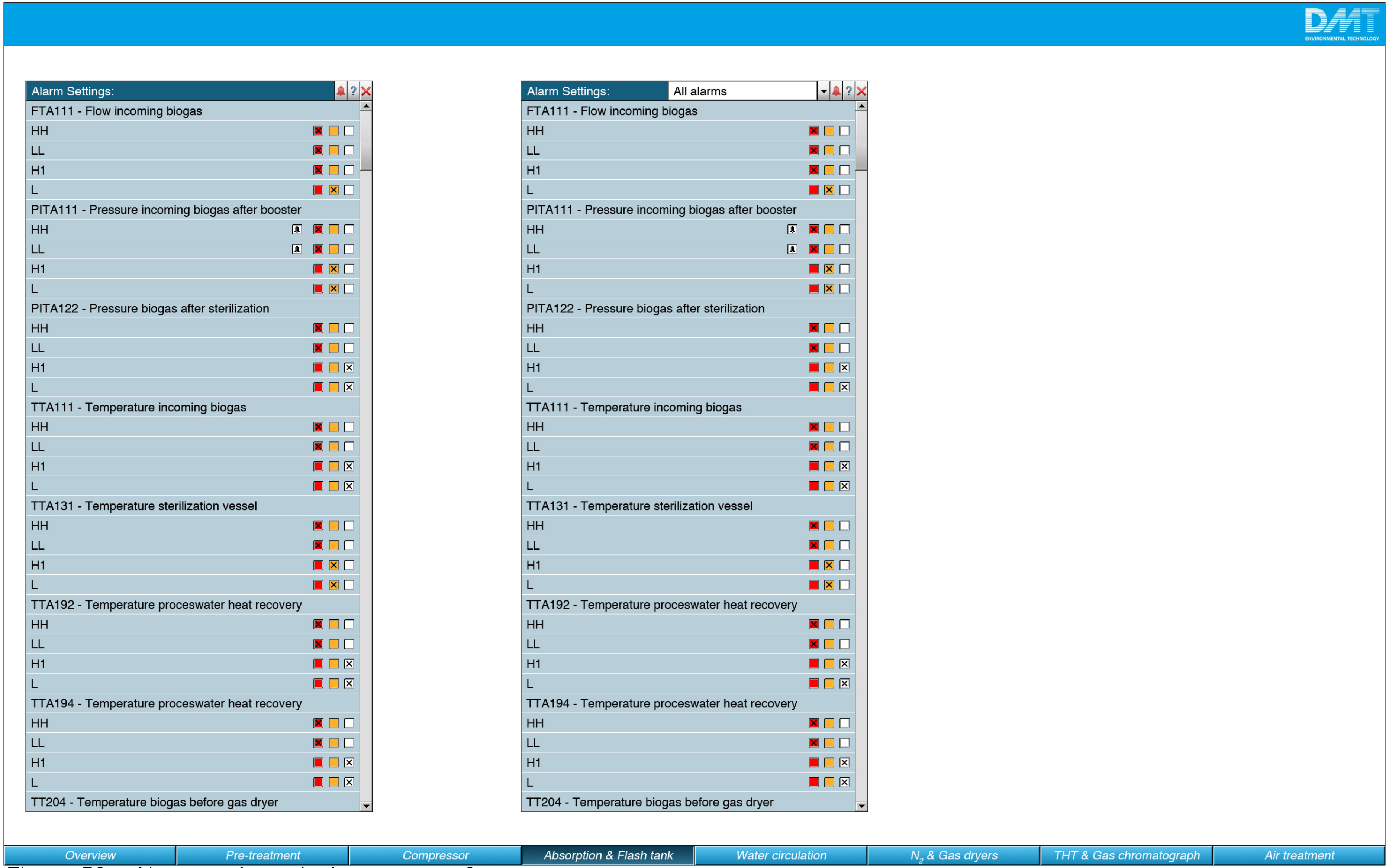


Figure 59 – Alarm settings design process 2.

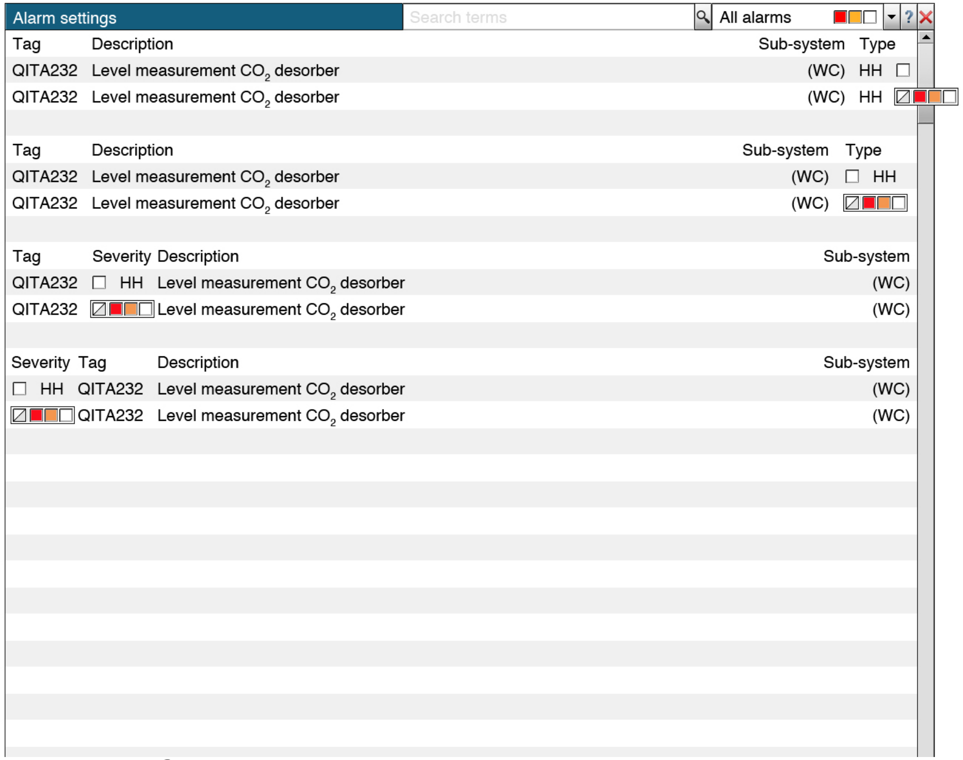


Figure 60 – Alarm settings design process 3.

The second option has been chosen for the alarm settings. Severity – Type are a data couple and are always shown in this order. User interface actions are usually placed after information about the change (Tag, Description and Subsystem in this case). The order of Severity – Type also ensures the pop up window to change the severity does not fall outside the screen.

The tabs to show different pages in a window (used in Alarm settings design process 1) were not chosen because of the extra noise it produces on the screen. Users are used to a scrollbar. Whenever there are more options than the window can show the scrollbar will appear. Using the scroll functionality will be natural for all users.

A simple drop down menu is chosen instead of buttons to filter the shown data on the screen. The drop down menu is integrated in the title bar, leaving more space for the alarm settings and reducing the amount of disturbing options on the screen.

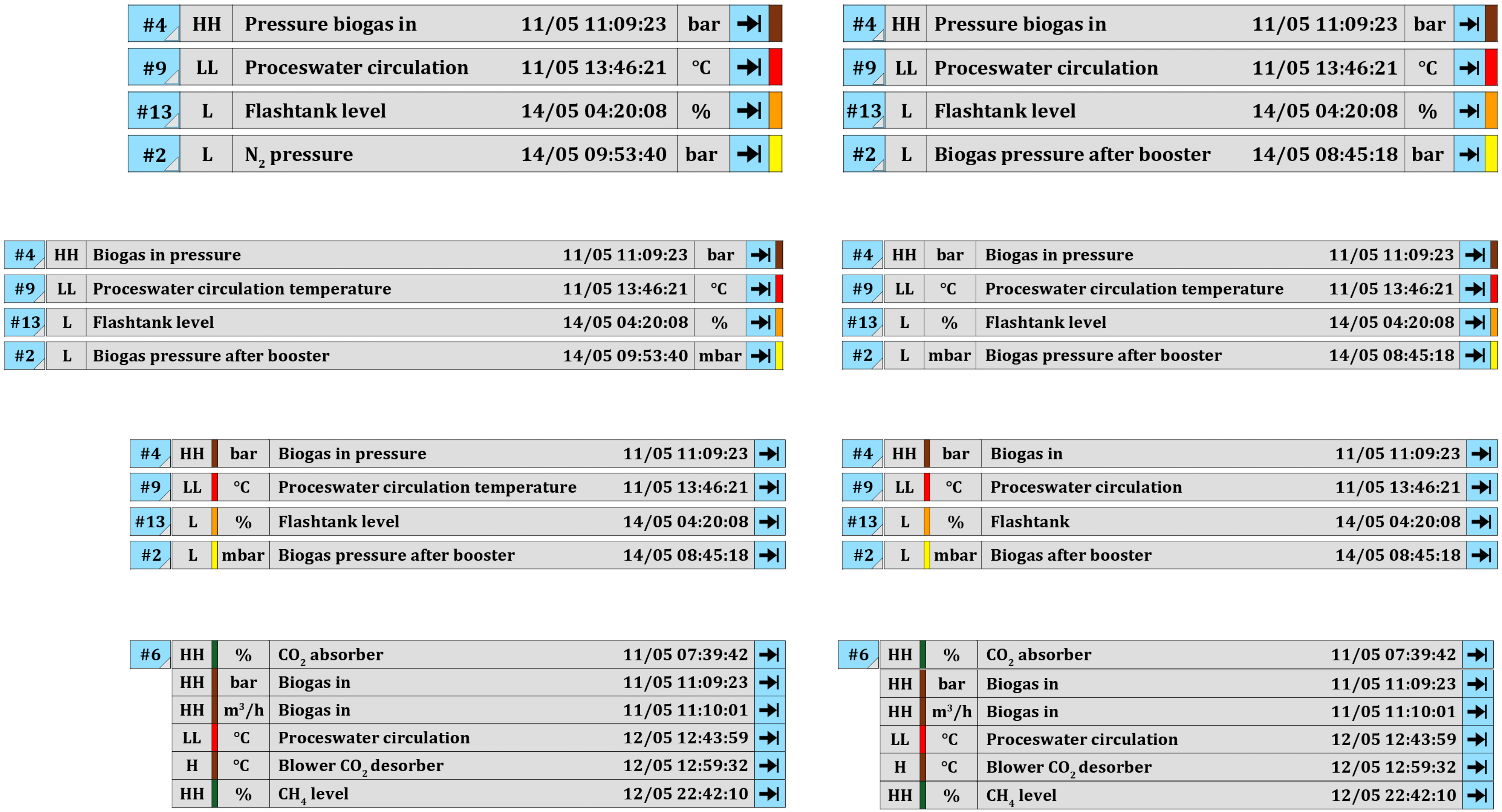


Figure 61 – Alarm bar design process 1.

The alarm bar still lacks some information like the subsystem the alarm is positioned in. The visualisation looks pretty prehistoric and there is no possibility to hide the frames.

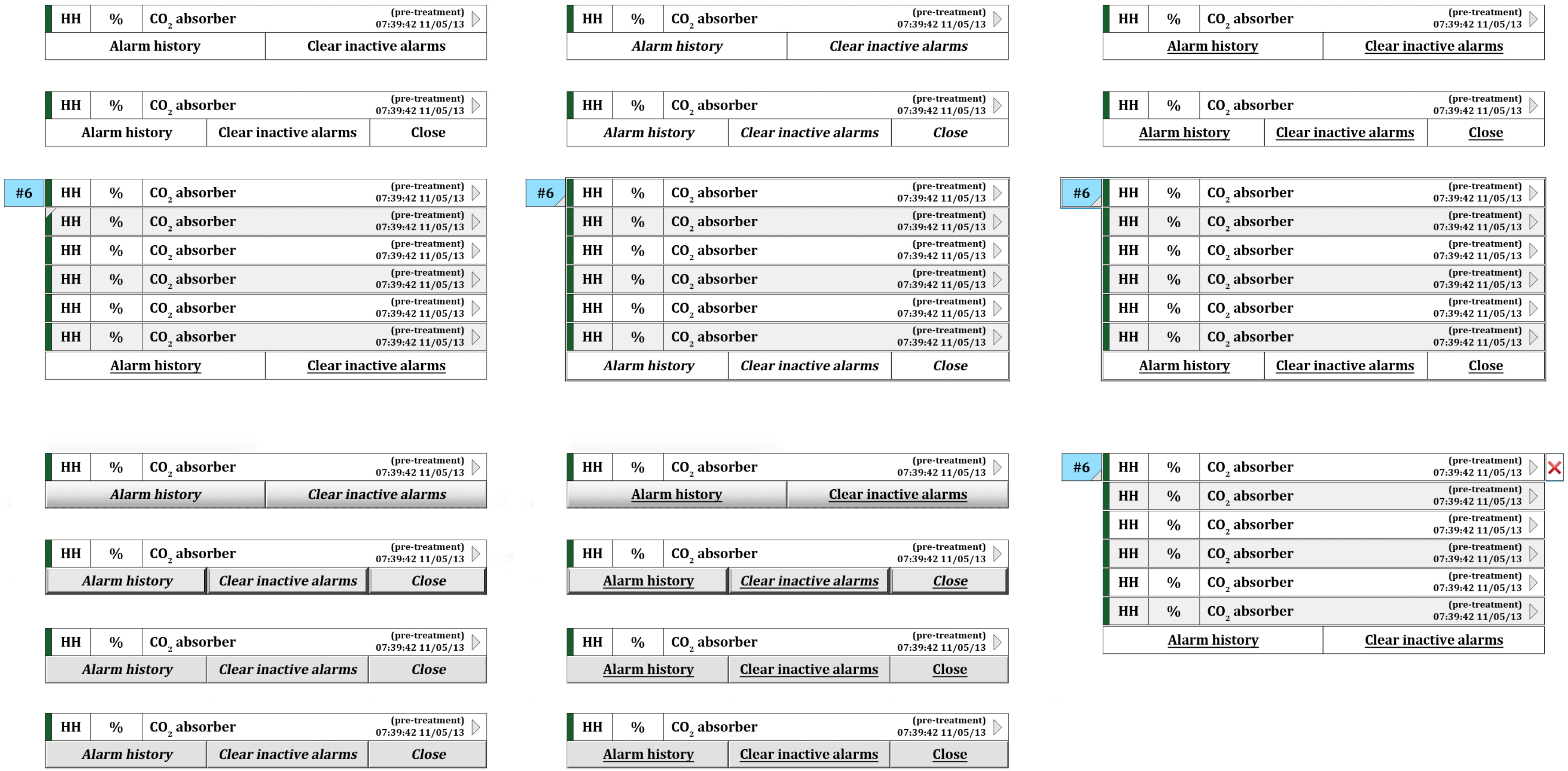


Figure 62 – Alarm bar design process 2.

The alarm bar does show the subsystem the alarm is located in and creates a link to the alarm history. Users can close the expanded alarm bar by clicking the cross button (last example) at the top right. The alarm bar still does not fully inform the user. The severity of the alarm is not visible and the parameter description and unit could be merged.

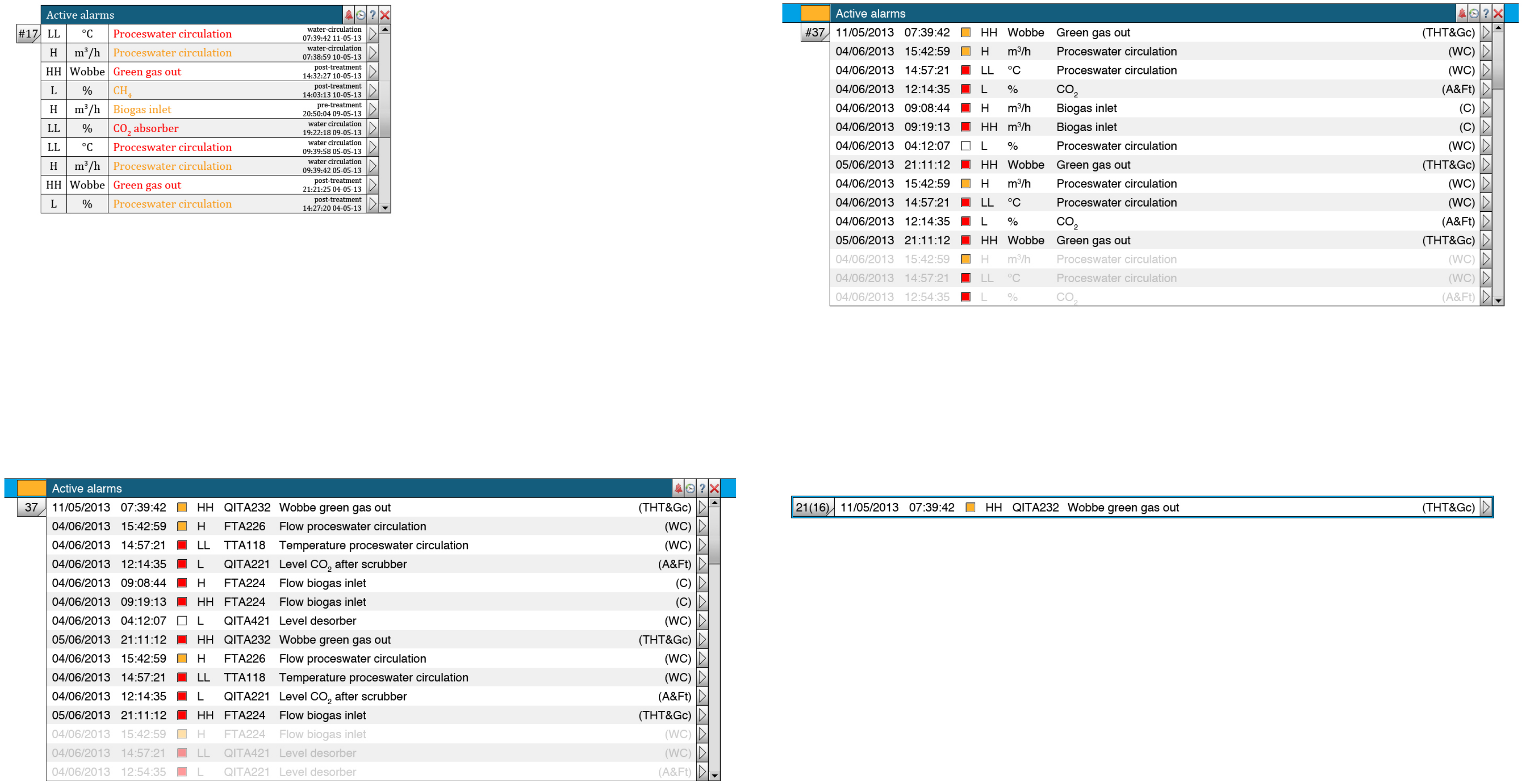


Figure 63 – Alarm bar design process 3.

The final alarm bar shows all the information the user needs and creates a link to the position of the alarm with the go-to button at the right side of the concerning alarm. The severity is indicated by the coloured square. A much easier to read state indication compared to the coloured description in the first example of this figure

Appendix D – Style sheet

Display settings	
Resolution	1280 x 800
Aspect ratio	16 : 10
Dpi	200 px/inch

Font settings	
Font	Helvetica
Font size	8 pt.
Font size parameter frame	6 pt.

Matter / parameter frame colour code	
Gas (yellow)	#FEE273
Water (green)	#255A28
N_2 (blue)	#34CAE5
Air (blue)	#34CAE5
THT (Purple)	#B771A2

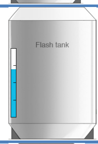
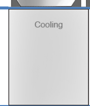
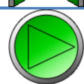
State colour codes	
Green	#46C700
Orange	#FFB228
Red	#C60001
Yellow	#FFF600
White grey	#E7E7E7

UI frame colour codes	
Top frame (DMT blue)	#00A1E5
Pop up frame (dark blue)	#145D7D

Pipeline data	
Thickness	10 px.
Minimum space between pipelines	10 px.

Data couples
Date & Time
Severity & Type
Tag, Description & Subsystem

Frame size	Percentage of total width/heig
Menu bar width (top)	100%
Menu bar height (top)	2,4%
Navigation bar width (bottom)	100%
Navigation bar height (bottom)	2,4%
Parameter frame width	6,4%
Parameter frame height	2,6%
Parameter frame expanded width	9,8%
Parameter frame expanded height	Variable
Parameter frame single bar height	1,3%

Part size	Percentage of total width/height	
Absorber	13 x 28%	
Desorber	11 x 26%	
Flash tank	13 x 12%	
Air treatment	11 x 26%	
Gas dryer	19 x 17%	
Black box components	10 x 8%	
Valve	5,1% x 1,8%	
Compressor	5,1% x 3,2%	
Motor	5,1% x 3,2%	
Subsystem state indication	1,9% x 1,2%	

Appendix E – UI Synchronisation 17/06/2013

Synchronisation of the user interfaces of the Sulfurex and Bio-Sulfurex and the PWS. The following points of interest and desired features will be synchronised.

Alarm severity
Alarms will be split in to different levels (e.g. Urgent alarms (coloured red), non-urgent alarms (coloured orange) and/or notifications (white)). The user interface must provide an option to change the severity of single alarms.

User levels
Interface will have different levels of complexity. Users can reach a higher level complexity by authenticating their selves. A higher level of complexity will offer more functionality and rights.

Grey and/or white input
The input field of parameters and/or data users cannot change are greyed out. To make change greyed out parameters another user with more rights is required. White fields are accessible for change.

Fast access to alarms
All alarms can be easily located by clicking on the alarm notification bar. Clicking it will show the window where the source of the alarm is in. This way, users do not have to search for the location of the alarm and it will be resolved quicker.

Parameter frame warning
Whenever an alarm occurs at a certain parameters the colour of the corresponding data frame will turn red. This way, users can locate the location of the alarm quicker.

Control function
To fully start or stop the plant both user interfaces have control buttons to do so.

Simulation
The user interface supports a function to simulate data. Simulated parameters must present themselves as different from standard input.

Matter colour
Colours used for different matters (e.g. air, water, gas, chemicals) are chosen conform the NEN 3050 standard.

Gas	Air	Water	Base
Flammable liquids	Steam	Extinguisher line	Acid

Logs
User interface provide visualisation for data logs the system keeps track of. If the data is presented it will be done in a fixed order:

Date – Time – Tag – Description – Sub-system – Alarm type – Value – User – Notes

Parameter list
User interface provide visualisation for a list of all parameters the installation contains. If the data is presented it will be done in a fixed order:

Tag – Description – Sub-system – Alarm type

Alarm (history)
User interface provide visualisation for a list of (the history of) alarms. If the data is presented it will be done in a fixed order:

Date – Time – Severity – Unit – Description – Sub-system – Date solved – Time solved.