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Efficient Plant Operation in Process Industries Using a User-Centric Design

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Modern industry relies heavily on automated technical processes, even in process industries. They help to produce products with a higher quality in less time, using less energy and raw materials. The degree of automation and the complexity of these processes are still increasing. Today, process control systems have graphical user interfaces that display an enormous amount of process information to be monitored by fewer and fewer operators. It seems there is no need for human control if a plant is fully automated. But if more automation is installed in a plant, the operators have less training in controlling the process manually. This can be crucial when exceptional process states occur. In such situations, operators have to make correct decisions to bring the process immediately back to a stable state. Due to a high degree of automation, operators do not have the opportunity to acquire the skills they need by controlling the process manually. In addition, long observation periods lead to reduced levels of vigilance. The likelihood of immediately detecting infrequent but important abnormal conditions is reduced. Furthermore, complexity from the operator's point of view is increased by a heterogeneous working environment involving different automation equipment and software products for process monitoring and control. It is exactly at this point that the innovative, user-centric design approach starts with its visualization concept for process monitoring and control. The distance between plant operators and production process is bridged based on an intuitive visualization of the current process situation. The objective of a user-centric design concept is to help engineers to develop and design human-machine interfaces that are more usable, therefore resulting in safer and more cost-effective process control. It starts in the design phase with operator workshops and it accompanies the production phase as a continuous improvement process. The graphical user interfaces provide optimum situational awareness, assist with decision making, enable immediate detection of exceptional process states, support with accurate operations, reduce operator workload, share best practice operations, provide training under real conditions, deliver homogeneous presentation of process information and target-oriented information.

1. Concept of user-centric process visualization

The display and operator control concept for plant operators has changed significantly in recent years.
Where previously mosaic panels were used for operator control, today the operator sits at a PC workstation with, for example, 4 screens. Until now, the benefits of the mosaic panel and recorder, such as clear representation of process states, were rarely adopted for PC workstations. Rather, the focus was on eye-catching graphics, which were of no great value in performing the actual operator task. Visualization systems and processes used today only achieve positive results in some areas; for example, individual plant sections or sub-processes can be clearly represented using graphic displays. According to the white paper "Modern plant control centers and operator control concepts" (Siemens AG, 2012), user-centric design supports the operative process control of industrial production processes by employing user-centric process visualization:

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The systems are characterized by:

- A variety of different devices and software products with non-homogenous operator interfaces (e.g. Distributed Control System, Management Execution System, Laboratory and Information Management System etc.)
- Multiple input and output devices per PC at the operator workstation
- Standard configuration of operator workstations (e.g. always 4 screens per client)
- Cost-driven workstation design

However, the processes used to represent process values have some weak points with regard to the following:

- Display of the overall status of the process – the "big picture"
- Visualization of processes is focused on instrumentation and normal operation
- Operators predominantly receive information through alphanumeric displays instead of analog displays with pattern recognition
- Attraction of the operator's attention using shape-coding and color-coding
- Task-related and activity-related visualization
- Display of information

The concept and design phases are also accompanied by conceptual weaknesses:

- Process pictures are created on the basis of isolated piping and instrumentation diagrams with a different display purpose
- Particularly in new plants, it is not possible to involve the operating personnel in the design process at an early stage
- Lack of a process visualization standard encompassing all graphical user interfaces
- Lack of process know-how in the design process
- Lack of ergonomic know-how in the design process

The user-centric design concept is described below (see Fig. 1).

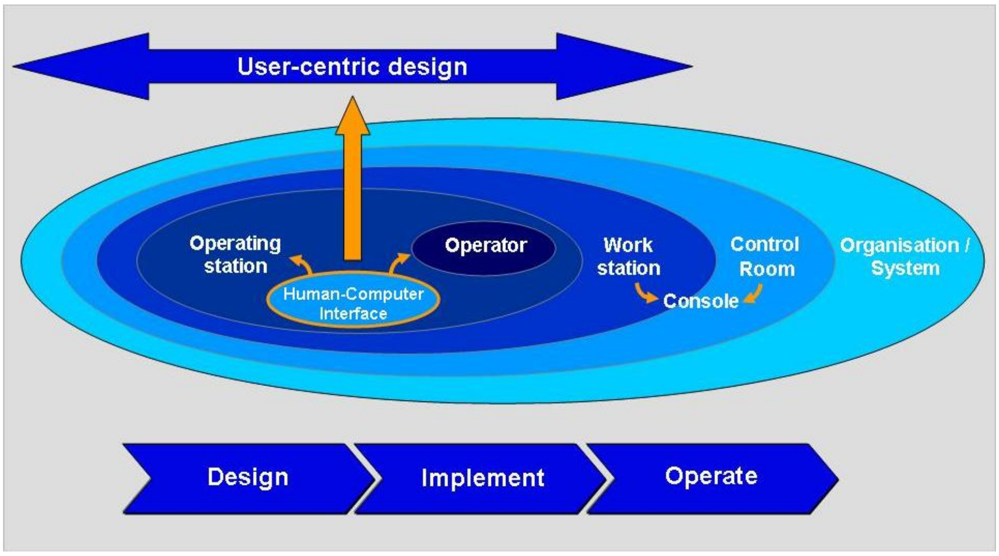

Figure 1: User-centric concept for designing industrial process control in accordance with EEMUA 201 (EEMUA, 2002)

This concept combines completely familiar elements and structures of operator control units – such as operator interfaces and their procedures – with the design of operator consoles and control rooms, and organizational measures to create a holistic approach to the solution.
The starting point is the detailed analysis of operator tasks with regard to process control and additional tasks in the control room area (see the examples in Table 1). This analysis must be carried out specifically for each plant on a project-related basis and with the involvement of the team of operators.

Table 1: Requirements for process visualization resulting from operator tasks

No.	Task	Job function	Activity	Requirements for process visualization
1	Process control	Monitoring an automated plant	Monitoring essential operating parameters (process-related KPIs)	Overview displays with essential operating parameters of the plant to be monitored Display of the permissible tolerances Display of limit violations Display of alarms and their priorities Analog displays for "pattern support" Trend displays for assessing situations and deciding on operating strategy
2	Process control	Monitoring an automated plant	Detecting/perceiving faults	Attracting attention by means of color scheme with distinct alarm colors Avoidance of cognitive overload
3	Process control	Monitoring an automated plant	Finding/identifying the cause of the fault	Jump function from alarm page to the measuring point in the process picture
4	Materials planning	Planning materials	Entering recipe parameters	Uniform and device-neutral presentation of the operator screen forms Use of the same input and output devices as for process control
5	Documentation for process control	Keeping a shift logbook	Entering the relevant process value in the shift logbook	Presentation of all relevant process values (in a log)
6	Extended quality Assurance	Monitoring of quality related process parameters	Monitoring of quality KPIs	Visualization of quality KPIs in overview displays of the process control system Device-independent, homogeneous presentation of the quality KPIs

In addition to project-specific issues, the following generally valid issues for improving process visualization have been derived from the prioritization of the requirements for process visualization (cf. Table 1):

Procedure for representing process values:

- Additional use of abstract operator procedures in which the process topology plays a subordinate role. For example: process-related overviews with essential operating parameters of the plant to be monitored using an arrangement of hybrid displays with tolerance and limit value visualization that supports pattern recognition. The operating parameters to be displayed are selected together with the operating personnel according to certain criteria. Around 80 % of operator input and monitoring during normal operation of the plant takes place using these overviews.
- Partial replacement of alphanumeric displays with analog displays, hybrid displays (analog and status display), and trend displays.
- Reduction in the complexity of the process displays thanks to task-oriented and process status-oriented selection of the process values to be shown (dedicated displays for start-up and shutdown, normal operation, load change and diagnostics).
- Use of a color scheme, including alarm colors
- Process pictures as a component in organizing the operator console
- Display of information instead of data, e.g. innovative display objects for temperature distribution, or trend curves for assessing situations and deciding on operating strategies

System solutions:

- Multifunctional, integrated operator workstation with homogenous operator interface, operator control with the same input/output devices
- Application of all individual devices in accordance with a device-wide design guide for process visualization
- Configuration of the operator workstation as part of the operator console layout
- Ergonomic design of the operator workstation
- Design of the control room as the working area for operators

Measures in the conceptual and design phase:

- Specify the process visualization concept in the design guide of the process visualization system
- Integrate the users (operating personnel) into the design process at an early stage. If this is not possible, the abstract displays must be created later in the optimization phase
- Involve experts with process know-how and human factors know-how

The concept is based on the rules and recommendations for the structure of displays where screen systems are used for process control documented in VDI/VDE 3699-2 "Process control using display screens - Principles" (VDI/VDE, 2005) and in VDI/VDE 3699-3 "Process control using display screens - Mimics" (VDI/VDE, 1999). The recommendations in this document are reflected in this concept and placed in the context of user-centric process visualization.

2. Display and operator control concept using the example of a continuous distillation column

The concept described in the previous section is explained below using the example of a continuous distillation column. The tasks of the operator of continuous distillation column are:

- Starting and shutting down the column
- Securing the process quality
- Avoiding the activation of protective devices
- Responding to process deviations
- Fast and safe interventions in critical situations

These tasks are taken into account in the display and operator control concept to guarantee an optimum working environment for the operator.
The detailed process displays are used for starting and shutting down the column (not described in this chapter). An overview display of the distillation column is selected for monitoring the process-related characteristic values (see Figure 2).

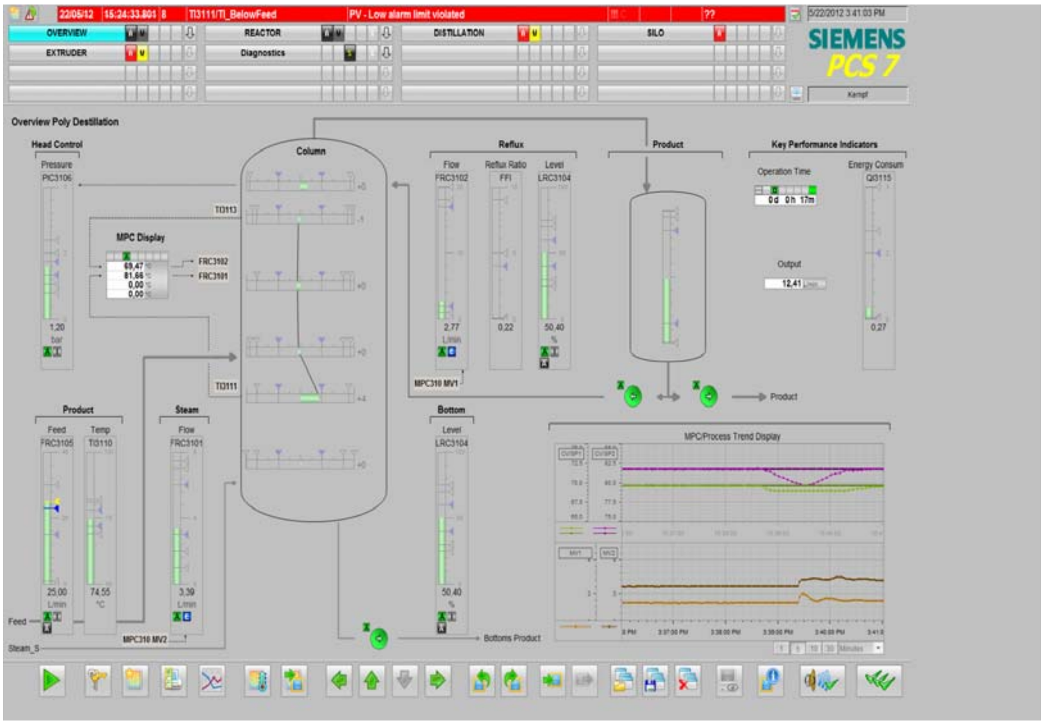

Figure 2: Overview display of the continuous distillation column

This contains the important process values and closed-loop controls of the distillation column. This display has the advantage that large volumes of data can be combined to present information in a condensed form. The important process parameters for monitoring are displayed using a combination of digital and analog displays, so-called hybrid display instruments. These hybrid displays and profile indicators, arranged as functional groups of process variables – for example for feed, for reflux, for temperature profile, etc. – support the operator in performing his routine duties as well as providing fast and safe interventions in case of process deviations and critical situations. The quality of a substrate separation is measured by the purity of the separation. The temperatures (TI3113 and TI3111) that can be easily measured are used as substitutional controlled variables. The "quality control" task by monitoring the temperature profile showing the optimal working range of the column is effectively supported by a display with the temperature profile on the operator screen (cf. Figure 3).

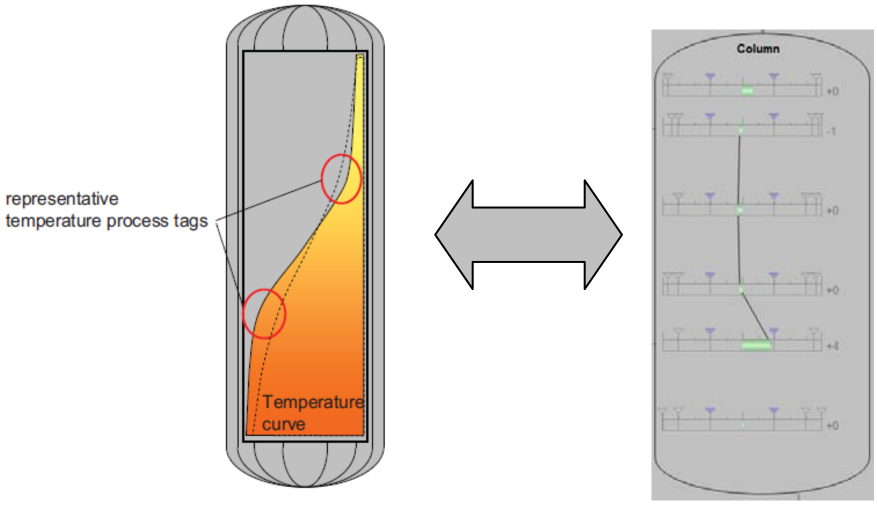

Figure 3: Display showing the vertical temperature profile of the column

In normal operation, the two relevant temperatures (TI3113 and TI3111) are essentially controlled by the model predictive controller (MPC). Major disturbances of the process, e.g. due to changes of the feed volume or the composition of the feed, are displayed by showing the trend of the controlled variables and manipulated variables.

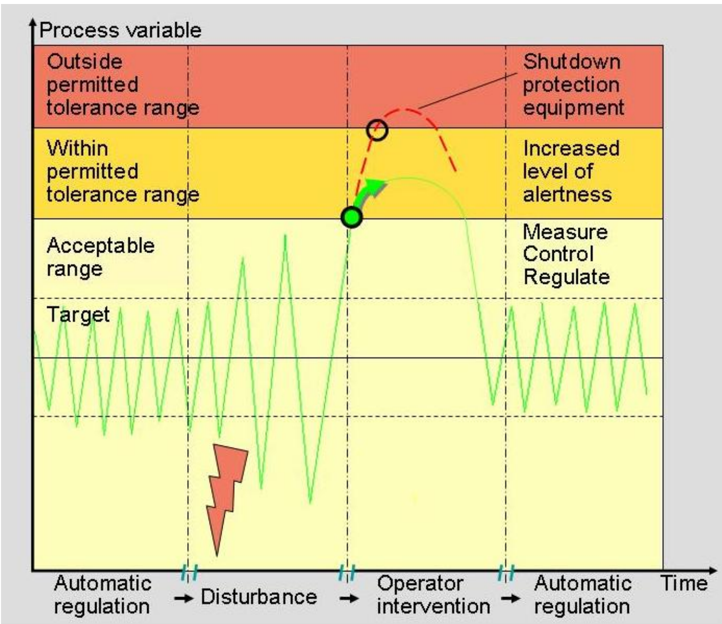

Figure 4: Process condition model of an automated process

As shown in Figure 4, the method becomes effective as soon as the acceptable range of important process parameters has been left. By using timely counter-measures, activation of protective devices or quality deviations of product can be avoided.
New hybrid displays (see Figure 5) enable the evaluation of important process values. These visualize the acceptable range for the process value. Otherwise, evaluation using an analog value would only be possible with the appropriate level of experience.

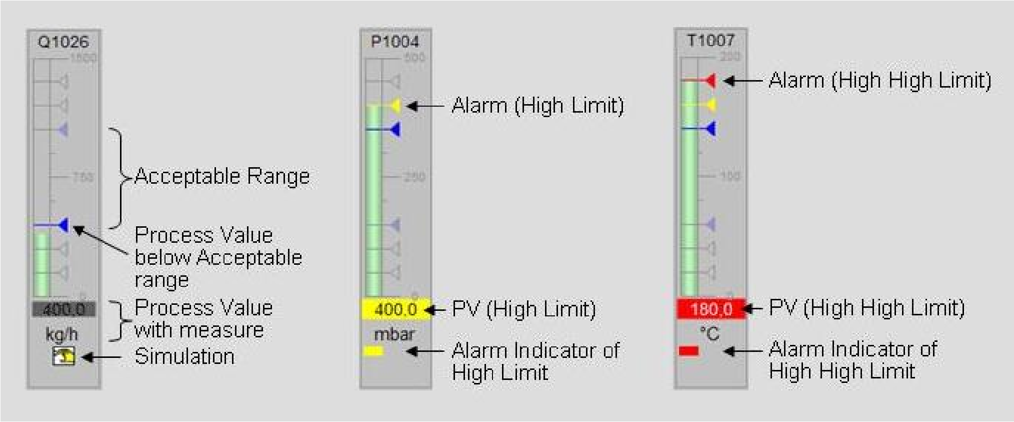

Figure 5: New hybrid display showing the acceptable range and alarms

3. Conclusion

The user-centric design concept discussed in this paper is intended to be a holistic solution approach for effectively coping with the increasing complexity of the processes to be monitored and the working environment in control rooms from the operator's perspective. Many aspects justify investment in modern human-machine interfaces or call for the redesign of traditional operator control concepts: safe operation of production plants by avoiding operator errors, extension of operator tasks, loss of operating know-how through fluctuations in employee numbers, and, last but not least, increased work load as a result of control rooms being merged. Initial experience in the application argues in favor of the use of these concepts (Glathe, L., 2012). By the use of user-centric design concepts it is possible to typically increase productivity by 5 to 12 % (ASM, 2009).

References

Siemens AG, 2012, Modern plant control centers and operator control concepts, whitepaper

EEMUA (The Engineering Equipment and Materials Users' Association), 2002, Process Plant Control Desk Utilising Human-Computer Interfaces – A Guide to Design, Operational and Human Interface Issues, Publication N° 201

VDI/VDE (Verein Deutscher Ingenieure e.V.), 2005, Process Control Using Display Screens - Principles, VDI/VDE 3699-2, Beuth Verlag

VDI/VDE (Verein Deutscher Ingenieure e.V.), 1999, Process control using display screens - Mimics, VDI/VDE 3699-3, Beuth Verlag

Glathe, L., 2012, Innovatives Bedienkonzept, Process news, 02-2012, 22-23

ASM (Abnormal Situation Management Consortium), 2009, Benefits <www.mycontrolroom.com> accessed 03.11.2012