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Developing a Human Machine Interface (HMI) for Industrial Automated Systems using Siemens Simatic WinCC Flexible Advanced Software

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ABSTRACT

Most industrial plants are automated without any operator-machine interaction. This makes it difficult for the operator to at a glance know the state of the machines and the immediate steps to undertake in order to clear any anomalies occurring in the plant. In this paper, consideration was given to the design of an HMI for an automated boiler plant which can be operated both manually and automatically by the press of start buttons. The design stages included screen interfacing for the HMI, flowchart development, programming the HMI by assigning tags, integration into Step 7 brand of PLC using ethernet, simulation of the program using "PLCSIM" and the programming codes of the automated boiler plant. The system gives a real-time view of the industrial plant, gives reduction in the troubleshooting time for faults and assures of safety of operating personnel. The designed HMI will be useful to manufacturing industries having industrial automated systems.

Keywords: *Industrial Automation, Human Machine Interface, PLC*

1. INTRODUCTION

Most industrial plants are automated without any interactions between the machines and the operator. This makes it difficult for the operator to at a glance know the state of the machines and the immediate actions and steps to undertake in order to clear any anomalies occurring in the plants. Maximum transparency and flexibility is essential for the operator who works in an environment where processes are becoming more complex and requirements for machine and plant functionality are increasing. The combination of emerging information technologies with traditional condition monitoring systems allows for the continuous running status monitoring for essential equipment as well as comprehensive data processing and centralised resource management [1]. Obvious advantages have moved companies from manual to automated forms of processing resulting in improved operational efficiencies, time savings, increased data accuracy, integrity and security and reduced manual entry costs. Essential to all automatic control mechanisms is the feedback principle, which enables a designer to endow a machine with the capacity for self-correction.

Major developments have occurred in the area of automation in recent years. The offered advantages of industrial automation are quality factor, improved productivity, optimisation of manufacturing operations, reduction of waste and labor costs and replacing humans in tasks done in dangerous environments such as fire, space, volcanoes, nuclear facilities, underwater, amongst others [2, 3]. The demerits of industrial automation cannot be overlooked: These are technology limits, unpredictable development costs, high initial costs and increase in the unemployment rate [3, 4].

HMI-based industrial automation systems have been reported in the literature in recent times. In reference to industrial automation systems in the field of Heating, Ventilation and Air Conditioning (HVAC), Attar et al. [5] designed sensor-enabled cubicles for occupant-centric capture of buildings needed to better serve occupants with improved comfort levels. A prototype system that includes data sensing, data storage and data representation to enhance the state of building performance visualisation using HMI was implemented. The hardware implementation was described where each cubicle was turned into a data-sampling cell distributed throughout a typical office floor. In [6] Building Automation Systems (BAS) where sensors are embedded into HVAC equipment to collect large amounts of data about the overall performance of a building were addressed. Differences however are not addressed at the user level due to coarse sampling and insufficient coverage of individual occupancy zones. Chou et al. [7] and Holmes [8] described a real-time data visualisation scheme on an HMI to create a "personalised and context-aware workplace" within an office space. Sensors were embedded into an office cubicle as a means to communicate various comfort-related factors to the user in real-time. Psychological impact of real-time data display as a potent tool for increasing a user's behavioral awareness was acknowledged. In [9] PLC code automatically generated not only works in ideal conditions when the process or production plant is up and running but also able to handle parts such as interlock logic, safety instructions, start-up and shutdown sequences. Four requirements were established to be able to auto generate PLC code. Volvo Car Corporation [10] created the HMI screens for their cars using Siemens WinCC. Since WinCC and Step 7 are highly integrated,

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the screens were created in the same project as the PLC code. In [11] automatic generation of PLC programs using automation designer software from Siemens virtual commissioning tools was developed. The purpose was to generate PLC code and HMI screens in an earlier phase of the commissioning and also to be able to reuse information created in Process Simulation software stored in a common database. PC-based automation for plant visualisation using WinCC Flexible and Visual Basic.NET was investigated into by Siemens AG. [12]. Data exchange was between controller WinAC RTX 2010 and visualisation occurs via a shared main memory area, which is provided by the Shared Memory Extension (SMX) interface of the WinAC open development kit. A Simatic HMI IPC477C was used for visualisation with WinCC Flexible. The data exchange between WinAC RTX and WinCC Flexible occurs via Softbus. A graphic surface represents data from the controller using control elements, such as input fields, buttons, graphic objects and animations. Flaspöler et al. [13] surveyed the literature on adequate ergonomic design, including HMI, as a priority for the European Union. This was aimed to raise awareness of the importance of adequate HMI as a vital factor for ensuring workers' occupational safety and health. Complexity of HMI leading to safety and health risks such as increased mental and emotional strain for users were explored. Patiño-Forero et al. [14] designed an elevator group control system using PLC and Destination Control System (DCS). Passenger flow was characterised to be highest in a heavy incoming traffic situation such as the traffic observed in the early hours of the morning. Novelty architecture for an elevator system was proposed by implementing a control strategy based on fuzzy logic using DCS. The architecture of the elevator group control system was designed in an industrial controller using DeviceNet industrial network based instrumentation and the DCS are modeled through HMI located at each floor.

Scott, Lance and Burton [15] designed a motion library for induction motors using an induction motor fitted with a 1024 pulse A/B phase incremental encoder, Sinamics G110 standard drive and an S7-200 CPU 224XP PLC with the programming software micro/WIN V4.0 SP6. The design allows the commissioning engineer to graphically view the speed, torque or position data of the move using the status trend function of Micro/WIN. Data was displayed on a touch panel or PC running WinCC Flexible. A simulation model importing existing geometry from Tetra Pak's CAD-software while logics and kinematics were added using Delmia Automation (DA) software was created by Joakin and Tobias [16]. The model was controlled by a virtual PLC through a virtual HMI. The purpose of the simulation was to discover such geometrical problems as collisions early in the development process. Bozzon et al. [17] proposed an innovative use of a mix of networking standards and software implementation technologies for the design of industrial HMI. The technologies that can be fruitfully used in the implementation of HMI architectures were analysed. The design of a real industrial HMI system that

exploits internet communication protocols and Web-based architectures was illustrated. Several advanced features such as application adaptivity, interface personalisation, control remotisation and multi-channel notification were achieved. The resulting platform in terms of performance, reliability and usability was finally evaluated. Free Scale Semiconductor [18] implemented an HMI using the Touch Sensing Software (TSS) library. There were two "Extra Credit" sections. The first shows how to add a second sensor and LED. The second shows how to view, touch, and release events in the CodeWarrior Debugger. The application note and hardware uses the Freescale Touch Sensing Software Evaluation Board (TSSEVB) or Freescale 8-bit MCU. The touch pad uses a touch sensor indicated by a LED.

This paper is aimed at developing an HMI for industrial automated systems which presents processed data to a human operator on a screen and through this the human operator monitors and controls the process. The developed HMI should be able to:

- Communicate with Siemens Simatic Step 7 brand of PLC;
- Give a very realistic view of industrial plant;
- Reduce hardware by replacing many push buttons, selector switches and lights;
- Replace humans in tasks done in dangerous environments; and
- Allow the operator to start and stop cycles.

2. MATERIALS AND METHODS

2.1 Basic Theory on Human Machine Interface

A Human Machine Interface (HMI) is a device for providing the means of controlling, monitoring, managing and visualizing device processes. With controls and readouts graphically displayed on the screen, the operator can use either external buttons or the touch screen to control the machinery [19]. HMI can also be defined as the interaction between a PLC system and an operator. The interaction is presented by a screen with dynamic icons, figures and text. An operator can monitor the production and control it to a certain level by the help of an HMI panel or PC [20]. As technology systems grow more complex, issues of end-product equipment safety, ease of operation and reducing the risk of human error are becoming extremely important. Designers today know that the operational performance, efficiency and safety of a wide range of systems are closely related to the interaction between humans and machines in other words the HMI. The selection and seamless integration of HMI components such as switch controls, actuators and indicators, are critical to the success of equipment designed for human operation [21]. The goal of interaction between a human and a machine at the user interface is effective operation and control of the machine and feedback from the machine which aids the operator in making operational decisions. The user interface includes hardware and software components. User interfaces exist

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for various systems and provide a means of input allowing the users to manipulate a system, and output allowing the system to indicate the effects of the users' manipulation. Poor design of HMI however can lead to bad temper and even to negative health effects such as frustration caused by depression as reported by [22]. The most important features of having HMI are high quality graphics for realistic representations of machinery and processes, alarms, trends, simulation, messaging, animation of equipment based on operator standards, hardware cost reduction and communication such as Serial Port (SP), Data Highway Plus (DHP), ethernet and Dynamic Data Exchange (DDE) [23, 24].

Siematic WinCC Flexible Advanced software is ideal for use as the HMI software in all applications in which operator control and monitoring is required on site

whether in production or process automation. WinCC Flexible Advance is Windows-based engineering software created by Siemens for producing HMI screens. The screens are available for use on Simatic HMI operator control and monitoring devices as well as standard PCs [25]. The programming interface of the WinCC Flexible Advanced software basically consists of the project view, property view, work area, tool pallet, output view and object view (Fig. 1). Fig. 2 gives the block diagram of the design concept of hardware and software.

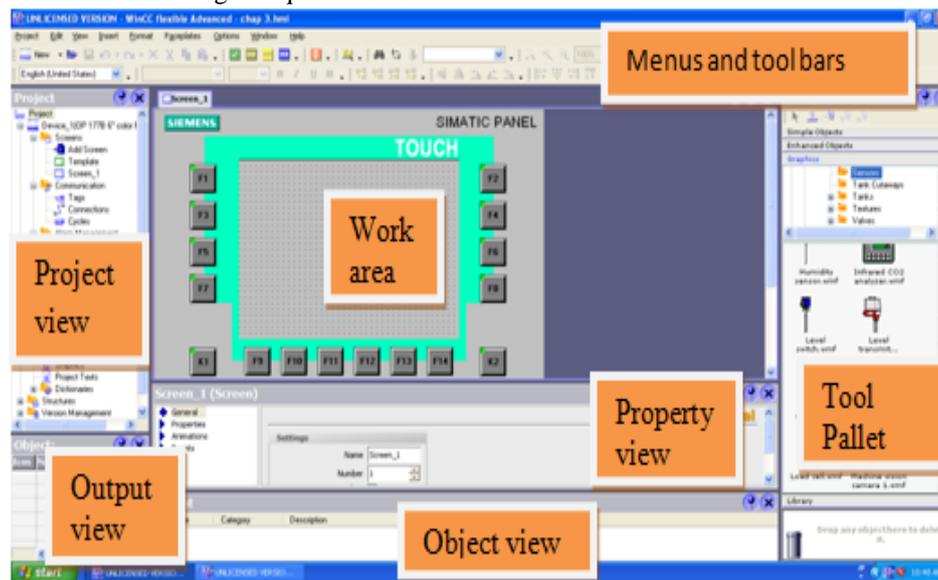


Fig 1: WinCC Flexible User Interface Elements

In terms of design criteria, the HMI should have the following features:

- Communicate with Siemens Simatic Step 7 brand of PLC;
- Give a very realistic view of industrial plant;
- Reduce hardware by replacing many push buttons, selector switches and lights;
- Replace humans in tasks done in dangerous environments; and
- Allow the operator to start and stop cycles.

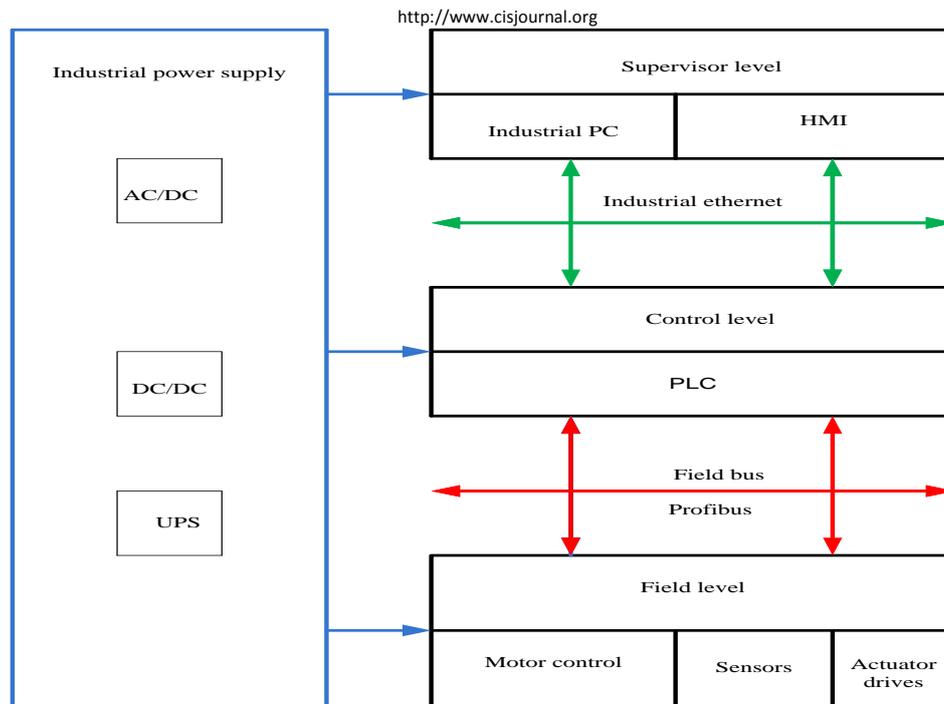


Fig 2: Block Diagram of the Design Concept

In the development of the HMI consideration was given to the design of a typical HMI for a fully automated steam generation boiler plant. The system basically consists of water and diesel reservoirs to feed water and diesel to the boiler. Pumps, digital valves with feedback control and level sensors are used to control the system. When the level of water or diesel inside the reservoir falls to a low level, the level sensors detect and send signals to open the valves so as to pump water or diesel into the reservoir. Also, the condensate water from the steam consumer is fed to a condensate tank and treated to remove hardness from the water. The condensate water after treatment is fed back to the boiler water reservoir to reduce the cost of municipal water supply for steam generation.

2.2 Materials

Both hardware and software components are required for the implementation of the HMI for the automated boiler system.

2.2.1 System Hardware

The required hardware are desk PC as the HMI screen, industrial ethernet as the link between the HMI and the PLC, profibus to connect the PLC and the field device, CPU 315-2 DP hardware and CP 341 PLC module where automation programs are executed, 24 V DC power supply and field devices such as analog level sensors, PT100, digital valves, non-return valves, water and diesel pumps, pressure transmitters/transducers and pressure relief valves.

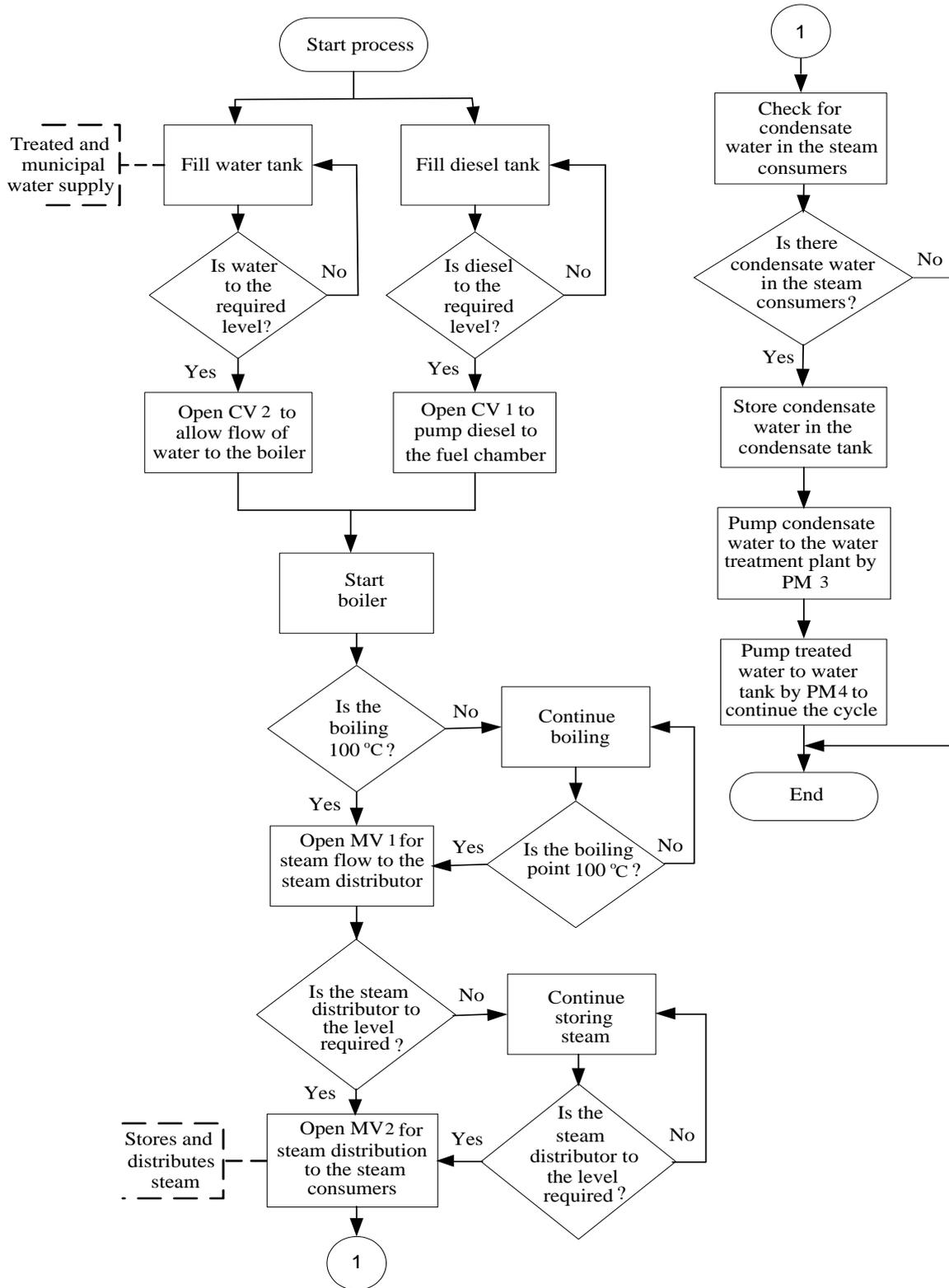


Fig 3: Flowchart for the Operation of the Automated Boiler Plant

2.2.2 System Software

Siemens Simatic WinCC Flexible Advanced and Step 7 software are the main softwares used for the programming of the HMI and the PLC respectively.

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2.3 Methods

For the methods, flowchart for the operation of the automated boiler plant is developed and presented in Fig. 3. Programming of the HMI is looked at and tags creation is affected. The HMI is then integrated into the industrial ethernet. Finally, simulation of the HMI and the PLC program are conducted using PLCSIM.

2.3.1 Flowchart for the Operation of the Automated Boiler Plant.

CV 1 and CV 2 are control valves, MV 1 and MV 2 are motor valves, PM 1, PM 2, PM 3 and PM 4 are pump motors. Any condensate water is stored in the condensate tank. The condensate water is pumped into the water treatment plant by PM 3 to remove any hardness and impurities present to enable the boiler to start boiling at 100 °C. The treated water is pumped into the water tank by PM 4 and the cycle continues as long as the system is in Auto mode. The automated boiler plant is designed to operate in both manual and automatic mode. In manual mode, the operator starts each of the machines sequentially by pressing the switches. Flowchart for the automatic mode is as shown in Fig. 3. The plant is operated by pressing the 'Auto' button after which the "Start Process" button is pressed for the plant to operate in the automatic mode. Operating in the automatic mode means that the protective and sensing elements check the system to ensure that everything is in the required order before initiating the process.

2.3.2 Programming the HMI of the Automated Boiler Plant

After generating the flowchart, programming the needed HMI starts with HMI creation and then, design of the automated boiler interface as preliminary stages.

Creating HMI for the automated boiler

To start WinCC Flexible software, either click the desktop icon on the programming device or select it from the windows start menu. It can also be started by: Clicking on start; All programs; Simatic; WinCC Flexible 2008; and WinCC Flexible. With the WinCC Flexible being opened, click on project menu and then click on "new" to create a new project. With this steps completed it will then take you to the device selection window where you select PC option and click the WinCC Flexible Runtime and then click OK in order to create PC based HMI for the boiler plant as shown in Fig. 4.

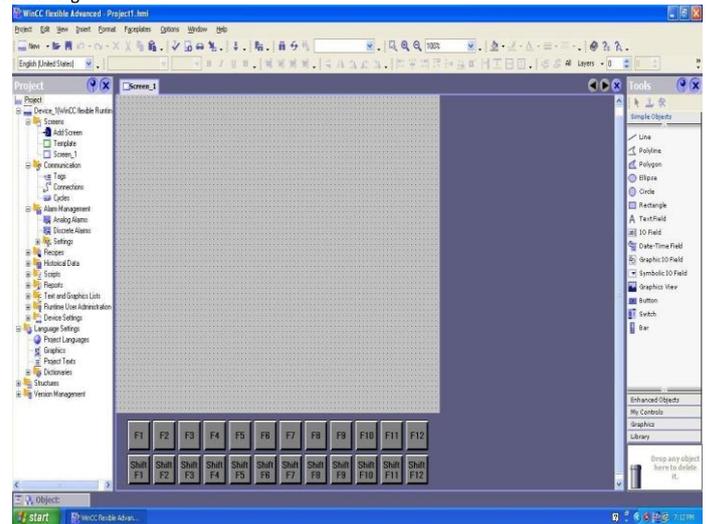


Fig 4: PC Based HMI Window

Design of the automated boiler interface

In designing the automated boiler interface, the design tool pallet in the right pane is used. The tools pallet contains several tools that can be picked and placed on the working area. They are then joined with the appropriate elements to form the design view. That is, say a pipe will be selected from the tools pallet and used to join the inlet and outlet of say a pipe or a pump to form a physical look of a connected valve or a pump. Fig. 5 depicts the right pane showing the tools pallet. After the design architecture, most of the control elements that initiate the operation, control and monitoring of the automated boiler plant are assigned appropriate tags. Fig. 6 shows control elements on the main screen.

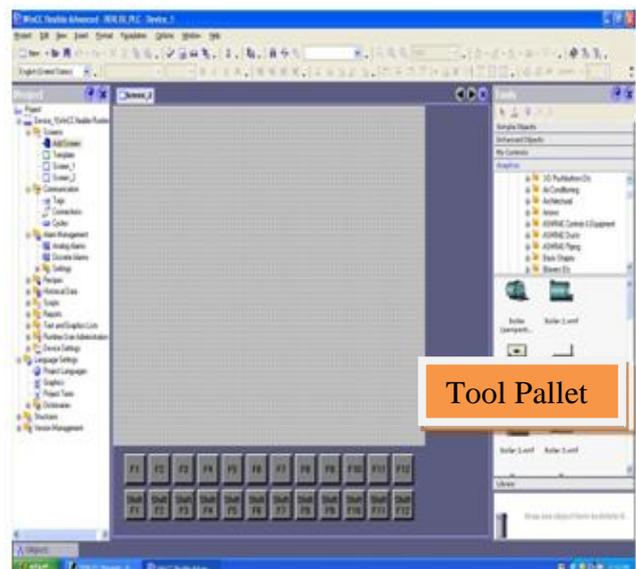


Fig 5: The Right Pane Showing Tools Pallet

The main screen consists of the control elements such as pipes, control valves, water treatment plant, water tank, diesel tank, municipal water supply, steam consumer, pump motors, steam boiler, condensate tank, steam

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distributor, and the manual, automatic, stop process and the reset buttons. There are other screens for alarm, warnings, status messages, parameterisation of the control valve in manual mode.

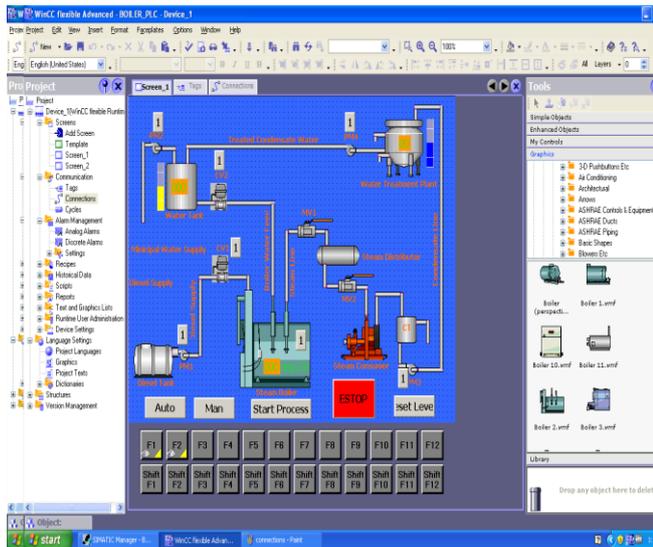


Fig 6: Control Elements on the Main Screen

Programming the HMI

Programming of the HMI involves assigning tags to screen elements. A tag is basically a link or connection between a screen element of the HMI and an address in the PLC. Tags are created in the tag window. By double clicking tags in WinCC Flexible, the tag window opens. To create a tag: First open the tag window by double clicking on tags in the left pane of the winCC Flexible program; Double click inside the tag window to create a default tag; Edit the default tag at the columns Name, Data Type and Address as shown in Fig. 7;

Name	Display name	Connection	Data type	Symbol	Address
BoilerStarted		Connection_1	Bool	<Undefined>	DB 10 DBX 9.3
Condensate_Pump_Runn...		Connection_1	Bool	<Undefined>	DB 10 DBX 10.3
CondensatePumpStart		Connection_1	Bool	<Undefined>	DB 10 DBX 8.6
Diesel_Feed_Valve_Open		Connection_1	Bool	<Undefined>	DB 10 DBX 10.2
Diesel_Pump_running		Connection_1	Bool	<Undefined>	DB 10 DBX 10.0
DieselPumpStart		Connection_1	Bool	<Undefined>	DB 10 DBX 8.5
ESTOP		Connection_1	Bool	<Undefined>	DB 10 DBX 9.4
Manchine_Auto		Connection_1	Bool	<Undefined>	DB 10 DBX 8.1
Manchine_Man		Connection_1	Bool	<Undefined>	DB 10 DBX 8.0
OpenDieselInletValve		Connection_1	Bool	<Undefined>	DB 10 DBX 9.0
OpenWaterInletValve		Connection_1	Bool	<Undefined>	DB 10 DBX 8.7
Process_Started		Connection_1	Bool	<Undefined>	DB 10 DBX 0.0
ResetLevels		Connection_1	Bool	<Undefined>	DB 10 DBX 9.5
Staem_Temp		Connection_1	Int	<Undefined>	DB 10 DBW 10
Start_Process		Connection_1	Bool	<Undefined>	DB 10 DBX 8.2
StarBoilerAutoMode		Connection_1	Bool	<Undefined>	DB 10 DBX 9.2
StarBoilerManMode		Connection_1	Bool	<Undefined>	DB 10 DBX 9.1
Water_Feed_Valve_Open		Connection_1	Bool	<Undefined>	DB 10 DBX 10.1
Water_Level1		Connection_1	Int	<Undefined>	DB 10 DBW 2
Water_Level2		Connection_1	Int	<Undefined>	DB 10 DBW 6
WaterPumpRunning		Connection_1	Bool	<Undefined>	DB 10 DBX 9.6
WaterPump1Start		Connection_1	Bool	<Undefined>	DB 10 DBX 8.3
WaterPump2Running		Connection_1	Bool	<Undefined>	DB 10 DBX 9.7
WaterPump2Start		Connection_1	Bool	<Undefined>	DB 10 DBX 8.4

Fig 7: Created Tags of the Automated Boiler Plant

Double click the next row of the tag window to create the next tag and so on; At the Address column, assign address in the PLC program to the tag to enable communication between the screen element and the PLC; and Click save to save the tags created.

Tag assignment to screen elements

To assign a tag to a screen element (e.g. the screen element labeled “Man”);

- Double click on the element say “Man” mode command button. This opens the tag property window;
- Click on the 'Events', option and then select “release” sub-option to the function list window as shown in the right pane. The release option creates a function to be initiated when the button is clicked and then released;
- Double click the first row to open the function list. In the function list, select “SetBit” to set the tag “On” when the button is clicked and released;
- Double click the row below row 1 in the function list window to open the tag window (opens a window showing all the tags created); and
- Select the tag whose bit is to be set when the “Man” command button is clicked and released. In this case, the “Machine Man” tag (i.e. puts the controls in manual mode) is selected.

The final window for tag creation is as shown in Fig. 8. The ‘ResetBit’ function above is assigned to the tag “Machine Auto” to serve as a soft interlock between manual and automatic modes of operation.

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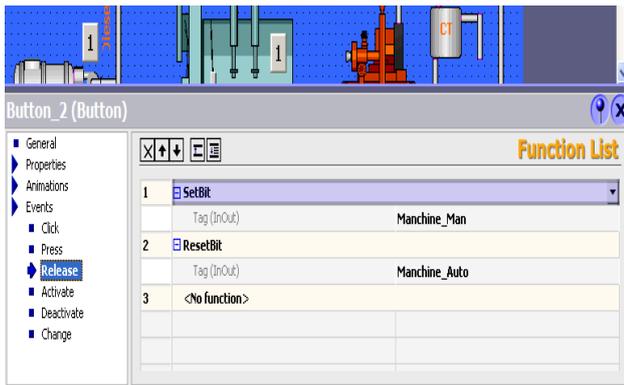


Fig 8: Final Window for Tag Creation

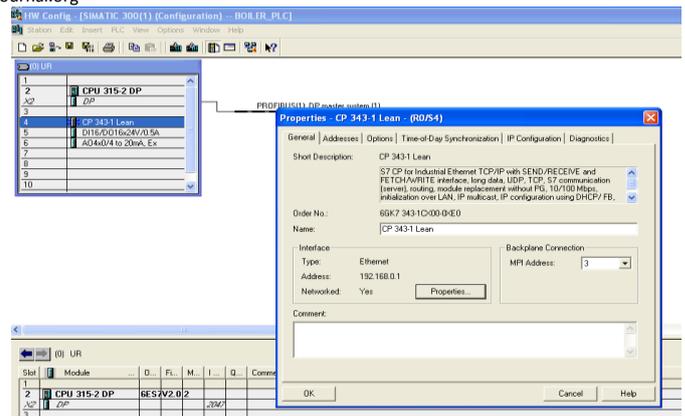


Fig 9: Property Window of CP343-1 Module

2.3.3 HMI Integration into Industrial Ethernet

The HMI is integrated into industrial ethernet using Siemens communication processor CP343-1 on the PLC assembly. The communication processor is the highlighted module in Fig. 9. The CP343-1 is assigned an IP address. To assign the CP343-1 a network IP address, the following steps are taken:

- Double click the CP343-1 module to open its property window;
- Click on properties in the above window to open another window;
- Click on new and then click OK to return to the screen in Fig. 9.
- Enter the IP address 192.168.0.1 and Subnet mask of 255.255.255.0;
- Click OK to exit the IP address entering window;
- Click OK again to exit the CP343-1 Properties window;
- Compile the configured hardware; and
- Download the compiled hardware configuration to the PLC through either MPI, ProfiBus DP interface or through industrial Ethernet cable after setting the correct PG interface.

The next stage in the integration process is to create an ethernet connection between the HMI and the Step 7 PLC through CP 343-1. To create an ethernet connection between the HMI and the PLC, open the connection window by double clicking connections in the project window (left pane) in WinCC Flexible. By double clicking the first row in the connections window, a default connection is set. Because the HMI program was integrated into Step 7, the default connection selects S7

300/400 under the communication driver column of the connection window. Accept all default entries. The next point is to select the ethernet under interface and then enter the IP address; 192.168.0.1 for the PLC and 192.168.0.2 for the HMI. The steps are as shown in Fig.10.

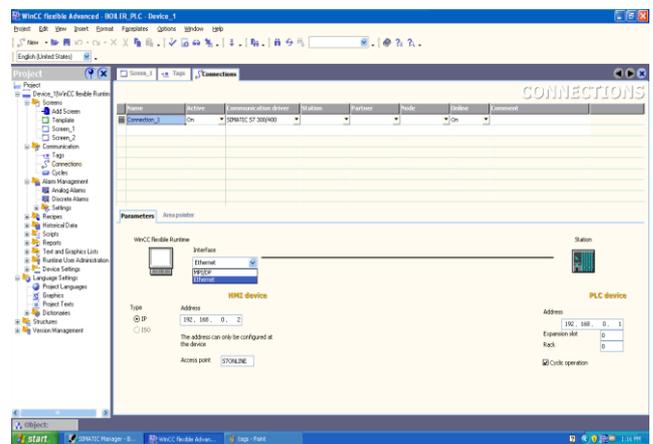


Fig 10: Ethernet Connection between the HMI and the PLC

2.4 Simulation of HMI and PLC Program

Simulation is used to test the response between the HMI program and the PLC program. The Siemens PLC simulator software, PLCSIM is used for the simulation. The simulation process is as follows:

- Open Simatic Manager;
- Click on the PLCSIM icon to open the PLC Simulator;
- Select the appropriate interface (PLCSIM(TCP/IP)) to transfer the PLC program;
- With the S7 PLCSIM opened, go back to Simatic Manager;
- Click Blocks in the left pane to select all the programmed blocks in the right pane. Finally, click on the download icon on the menu bar to download the program to the PLC;
- Switch the PLCSIM CPU into run mode by checking the run option on the CPU window;

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- With the PLCSIM in run mode without errors, open the function block FC10 in Simatic Manager and click on ‘monitor’ to see how the program is running;
- For the next testing process of switching the HMI program also into runtime or simulation mode is achieved by clicking on the runtime or simulation icon shown in Fig. 11; The step 7 launches the HMI program in runtime mode; and
- With the PLC block FC10 in monitoring mode, click the ‘Man’ command button on the HMI. Check in the PLC programmed block FC10 to see if the tag for the 'Man' command button which is assigned an address DB10.DBX8.0 is activated.

Runtime Icon

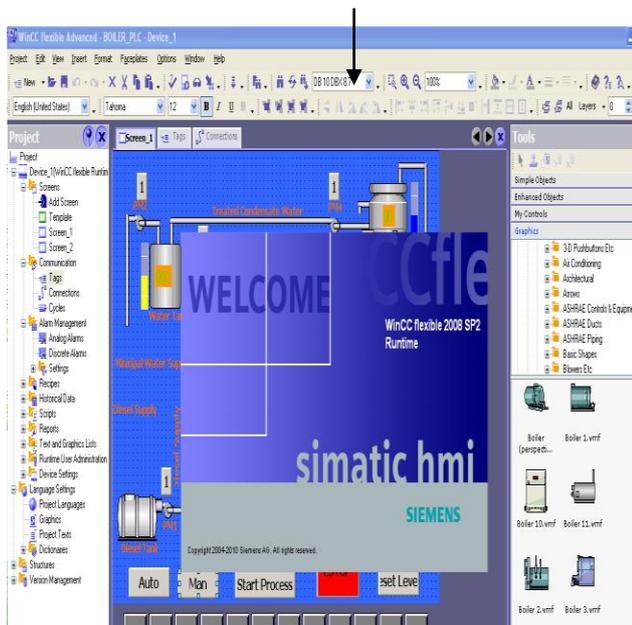


Fig 11: Starting WinCC Flexible Runtime

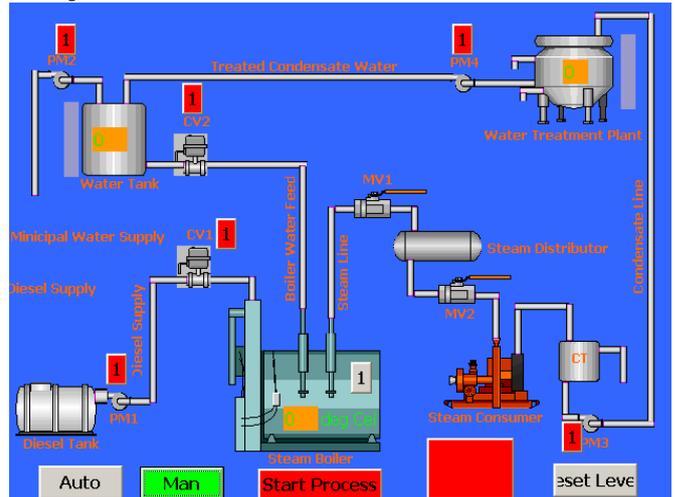


Fig 12: Manual Mode of Operation of the Automated Boiler Plant

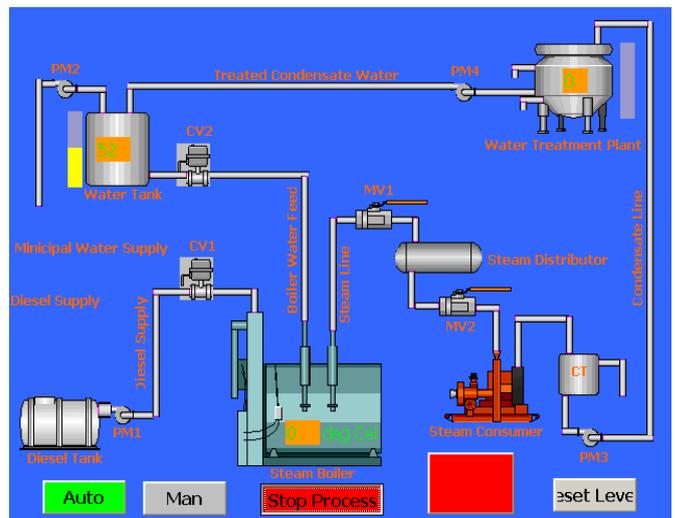


Fig 13: Automatic Mode of Operation of the Automated Boiler Plant

3. RESULTS AND DISCUSSION

3.1 Simulation Results

Testing the functionality of the automated boiler plant is designed in such a way that in runtime when operating in the manual mode, the manual button indicates green and all the other switches on each component indicate red and turn green when the operator presses the switch as shown in Fig. 12. The automatic mode is activated when the ‘Auto’ button is pressed indicating green. The system starts automatically by performing system checks on the plant before the process is initiated. It then controls itself automatically without any human intervention. Fig. 13 depicts the automatic mode of operation of the automated boiler plant.

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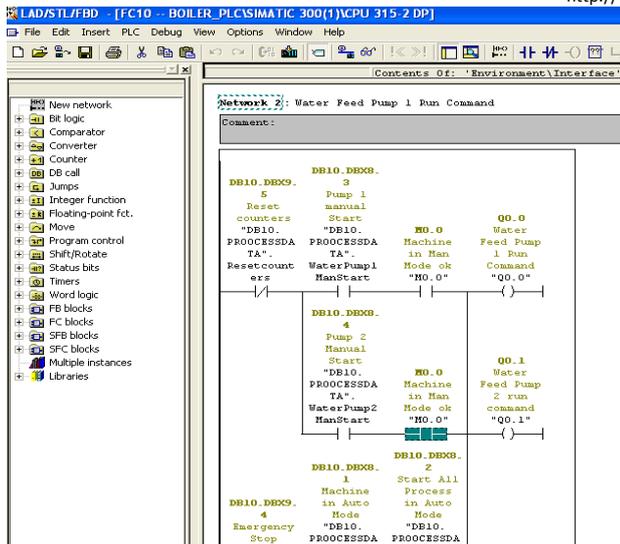


Fig 14: Water Feed Pump 1 Run Command

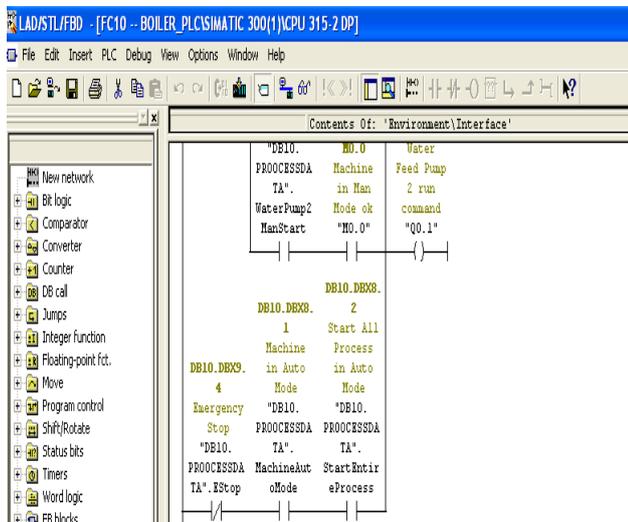


Fig 15: Water Feed Pump 2 Run Command

3.2 Discussion of Simulation Results

Successful programming of the designed HMI was as a result of correct tag development for the screen elements to mimic the real-time state of the industrial plant. Successful communication between the HMI and the PLC was trustworthy and facilitated by the tagging system. Manual and automatic modes of operation are availed by way of pressing soft-touch switches. By good design, automatic mode is assured without human intervention.

4. CONCLUSIONS

The design of HMI using Siemens Simatic WinCC Flexible Advanced software has been achieved. Simulation of the program using "Simatic PLCSIM" was conducted to check the functionality of the PLC program created. Simulation results validated the correctness and applicability of the generated HMI program. The designed

HMI is commensurate with: A real-time view of the industrial plant; reduction in the troubleshooting time for faults; and safety of operating personnel. Manufacturing industries can easily adapt to the implementation of HMI as part of their industrial automation systems to make process visualisation of the plant easier, locate faults rapidly and to help replace humans in tasks done in dangerous environments.

REFERENCES

- [1] L. Wang, K. C. Tan, "Design Principles of Modern Industrial Automation Systems", The Institute of Electrical and Electronics Engineers, Inc, 10pp, 2006.
- [2] Anon. "Automation", www.altiusdirectory.com/Business/automation.html, 2010.
- [3] J. Selender, "Control System Expert VCC", (M. Andersson, & E. Helander, Interviewers) Göteborg, Sweden, 2010.
- [4] Anon. "Automation", www.en.wikipedia.org/wiki/Automation, 2009.
- [5] R. Attar, E. Hailemariam, A. Khan, S. Breslav, G. Kurtenbach, "Sensor Enabled Cubicles for Occupant-Centric Capture of Building Performance Data", MSc Thesis Report, Design Research Associate at Autodesk Research, Toronto, Canada, 8pp, 2005.
- [6] Z. Mo, A. Mahdavi, "An Agent Based Simulation Assisted Approach to Bilateral Building Systems Control", Proceedings of the IBPSA, Eindhoven, Netherlands, 887pp, 2003.
- [7] P. M. Chou, J. Gruteser, A. Lai, S., Levas, C. McFaddin, M. Pinhanez, D. Viveros, S. Yoshihama, "Blue Space: Creating a Personalized and Context-Aware Workspace", IBM Research Report, Yorktown Heights, NY, 98pp, 2001.
- [8] T. Holmes, "Eco-visualization: Combining Art and Technology to Reduce Energy Consumption in Creativity and Cognition", Washington, DC, pp. 153-162, 2007.
- [9] K. Güttel, P. Weber, A. Fay, "Automatic Generation of PLC Code Beyond the Nominal Sequence", Emerging Technologies and Factory Automation, Hamburg, Germany, pp. 1277 – 1284, 2008.
- [10] Volvo Car Corporation, "Programming Instructions for PLC Systems Simatic S7", 2008.
- [11] M. Andersson, E. Helander, "Automatic Generation of PLC Programs using Automation Designer Based on Simulation Studies and Function Block

<http://www.cisjournal.org>

- Libraries”, MSc Thesis Report, Production Engineering, Chalmers University of Technology, Göteborg, Sweden, 101pp, 2010.
- [12] Siemens AG., “PC-based Automation Plant Visualisation with WinCC Flexible and Visual Basic.NET”, www.support.automation.siemens.com/WW/view/en/, 2011.
- [13] E. Flaspöler, A. Hauke, P. Pappachan, R. Dietmar, Bleyer, T. N. Henke, S. Kaluza, A. Schieder, W. Armin, S. Salminen, J.C. Blaise, L. Claudon, J. Ciccotelli, L. Eeckelaert, M. Verjans, K. Muylaert, O.D.B. Rik, “The Human- Machine Interface as an Emerging Risk”, The European Agency for Safety and Health at Work, 40pp, 2006.
- [14] A. A. Patiño-Forero, D. M. Muñoz, G. Caribé de Carvalho, H. C. Llanos, “Modeling of an Elevator Group Control System using Programmable Logic Control and Destination Control System”, ABCM Symposium Series in Mechatronics, University of Brasília, Department of Mechanical Engineering, Brasília, Vol. 4, pp.433- 441, 2010.
- [15] W. Scott, B. Lance, B. Burton, “Motion Library for Induction Motor”, Abacus Automation, South Africa, 22pp, 2008.
- [16] D. Joakim, S. Tobias, “Interactive Control of a Virtual Machine”, MSc Thesis Report, Lund University, Department of Industrial Electrical Engineering and Automation, Sweden, 116pp, 2005.
- [17] A. Bozzon, M. Brambilla, P. Fraternali, P. Speroni, G. Toffetti, “Applying Web based Networking Protocols and Software Architectures for Providing Adaptivity, Personalisation and Remotisation Features to Industrial Human Machine Interface Applications”, MSc Thesis Report, Polytechnic of Milan, Department of Electrical and Information, Italy, 15pp, 2003.
- [18] Free Scale Semiconductor, “How to Implement a Human Machine Interface using the Touch Sensing Software Library”, [www.freescalesemiconductor](http://www.freescalesemiconductor.com), 2009.
- [19] Anon. “Industrial Automation Solutions- Human Machine Interface”, www.ti.com/general/docs/getlitature.tsp, 2011.
- [20] Siemens AG Automation and Drives, “Operating Manual for WinnCC Flexible 2008 Compact/Standard/Advanced”, www.automation.siemens.com/salesmaterialas/brochuresimaticwincflble n.pdf, 2008.
- [21] Anon., “Designing Effective Control Interface Systems”, www.ewark.com/pdfs/techarticles/ea, 2012.
- [22] F. Sarodnick, H. Brau, “Methoden der Usability Evaluation”, Wissenschaftliche Grundlagen und praktische Anwendung. Huber: Bern, 2006.
- [23] Anon. (2011b) , “Krono Tech Instrumentation and Control”, www.kronotech.com/HMI/advantages.htm, 2011.
- [24] F. Nachreiner, P. Nickel, I. Meyer, “ Human Factors in Process Control Systems: The Design of Human Machine Interfaces”, Safety Science, Vol. 44, pp 5-26, 2006.
- [25] Siemens AG Industry Sector, “Simatic WinCC Flexible Brochure March 2010”, www.automation.siemens.com/salesmaterial-as/brochflbleuresimat icwinccn.pdf, 2010.