Building Control, Monitoring, Safety and Security
using Collaborative Systems

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Abstract **- This paper describes the use of SIEMENS S7-300 PLC's and SIEMENS SIMATIC WinCC software in creating collaborative systems for controlling and monitoring modern buildings. These systems assure also the safety and security of the buildings. The communication between PLC's and WinCC software is made using SIEMENS PROFINET technology.**

Keywords – Building Automation System; PLC; WinCC; Redundancy; HVAC; HAS; SCADA; HMI

I.INTRODUCTION

- For achieving energy efficiency and enhancing the living and working standards of occupants, building owners are increasingly seeking automation management systems. However, each building is unique due to architectural, structural, and dimensional variations, as well as differences in occupants' preferences, schedules, needs, and cultural factors. This necessitates tailor-made automation algorithms for individual buildings. Yet, for certain building types, like hotels, a standardized automation platform can be employed, allowing- the development of generalized algorithms that may be applicable across different structures. Collaboration among building programmers is crucial for crafting algorithms suitable for various automation systems.

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- Both Home Automation Systems (HAS) for residential areas and Building Automation Systems (BAS) for large structures such as office buildings, hotels, hospitals, malls, supermarkets, schools, etc., focus on controlling and monitoring various aspects. These include lighting systems, HVAC (heating, ventilation, and air conditioning), energy management, security and access control, safety alarms, remote surveillance, and other functionalities like window blinds, communication systems, elevators, irrigation, water supply, audio/video controls, de-icing systems, and garage/gate controls. Both HAS and BAS emphasize local, central, and remote access to building devices and functions, with central monitoring and control equipment accessible through wireless or wired devices, resulting in significant cost reduction.

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- A Building Automation System is structured across five levels: design, field, automation, energy management, and technical surveillance. The design level involves developing the automation system architecture concurrently with building construction. The field level comprises sensors and actuators interacting with the physical environment. Automation control is executed at the automation level, housing PLCs, CPUs, and computers/servers running SCADA software. The energy management level features algorithms and schedule programs aimed at reducing energy consumption. The technical surveillance level integrates software algorithms and hardware components for fault detection and automatic resolution (fault tolerance) or alerting operators through human-machine interfaces (HMI). Early-stage fault detection and localization are crucial at this level to safeguard other components of the system.

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This paper proposes a Building Automation System based on a decentralized architecture, where each zone or equipment complex (e.g., ventilation units) is served by a node containing a PLC. Nodes are interconnected through a network using Industrial Ethernet protocols, facilitated by PLC Ethernet extension modules or integrated Ethernet ports. The use of Industrial Ethernet provides five main benefits: [Details of benefits can be elaborated here based on the context.]simple hardware implementation of the network;

- reduced hardware cost;
- online maintenance - faulty nodes can be debugged, stopped and maintained without influence on other nodes;
- online expansion for future developments - new nodes can be added in the system without influence on other nodes and the WinCC interface can be modified with new pages, tags and elements without influence on hardware part of the system;

- online add, move, remove or modify distance monitoring dispatchers.

The redundancy of the monitoring and control equipment is very important in large building, where the budget allows redundant implementations. Redundancy consist in installing multiple servers that have direct access to the field PLC's through a network realized with distribution equipments that permit dual connection. The authors in [1] present the basis of using WinCC software in making Building Automation System projects. In [2 and 3] autonomous and collaborative building systems are described. The software redundancy by using multiple servers is presented in a more complex way in [4] and the redundancy of the networks using ring topology is presented in [5]. The documentations [6, 7, and 8] show the way for configuring and programming PLC's. Communication steps are presented in [9, 10, 11, 12, 13, and 14].

II. System Schematic

A building automation system consists in elements like sensors, actuators, controllers and controllers cabinets named nodes (where are the fuse protections, power supplies, electronic components and drives between controllers and actuators). These elements placed in the building are connected to the controllers inputs/outputs. When the building automation system is implemented and properly configured the data from all processes can be acquired and operators have access to installations processes control through a WinCC HMI.

The presented system addresses to big buildings like hospitals, hotels, malls, big office buildings. This system contains two servers, two clients, the industrial Ethernet communication network and twelve PLC's dedicated for Lighting Control, Window Blinds Control, HVAC, Energy Consumption Management System, Safety Alarm System, Security and Access Control, Intercom Control, Public Address Audio System Control, De-icing System, Water Supply and Irrigation System, Elevators Control and Gates Control.

As a possible extension of the system , a possible number of thirty-two clients can be connected to a WinCC server or servers. Maximum twelve servers can be included in the system. A generalized schematic of the system is presented in Fig. 1.

For the proposed building automation system a redundant WinCC configuration is implemented. The redundancy configuration consist of two servers that perform the same functions but not simultaneous. One server, marked as master (server1) runs all the time and one standby server (server2), which is programmed to start only when the master server fails. The clients start to communicate with the standby server (server2), which acquires data from the building. We use a KVM for using a single keyboard and mouse for both servers. The Ethernet Network is implemented using SCALANCE switches, that are SIEMENS products, with ring topologies using twisted pair cable and fiber optic.

All the equipments are borrowed from industry making local processes to work in real time and give to the building automation a high precision.

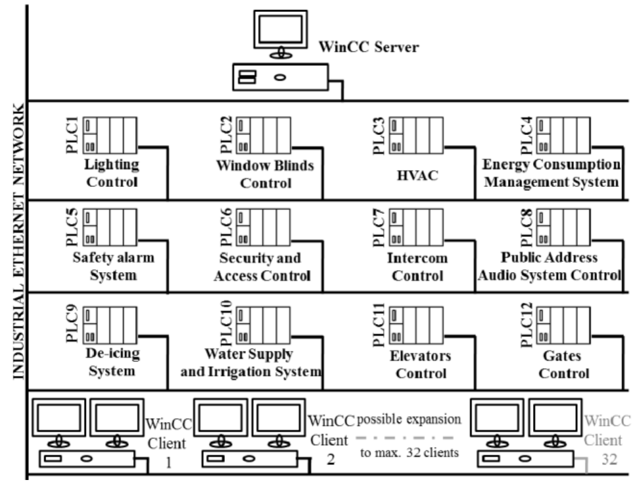

Figure 1. Generalized diagram of Building Automation System

III. System Implementation

For field on-line monitoring this system uses a computer/server on which runs SIEMENS (company) application named SIMATIC WinCC, version 7.0. All the data acquired from the building with the analog/digital modules are transmitted by the PLC's through the real-time Industrial Ethernet Network to this computer/server that is equipped with an Industrial Ethernet PCI board.

From introduction we established that algorithms developed on a specific kind of building can be generalized for other building using the same basic platform. This can be possible by collaboration between programmers of the automation system. And for errors and bugs technicians can have a major impact by consulting with technicians from other building with the same platform and notice to the programmers the problems using software implemented reports section. These reports can be ported to all buildings using same platform.

A good method for implementing building automation algorithms for reducing energy consumption is by using prediction. Building automation systems have to use a central database of control algorithm rating which is explained in [3]. With the measured values the building processes can be simulated for preliminary algorithms tests. Multiple algorithms can be automatically selected and used by the system, for instance winter/summer regime. The proposed system uses algorithm prediction. This system allows different implemented algorithms to be selected and on-line uploaded in PLC trough the Ethernet Network. WinCC dispose of a database with acquired values from the building sensors and actuators, so prediction can be used in algorithms implementation. An example is turning on and off lights in the building rooms. Instead of using only presence detectors, we can predict from database measured values when and where the light is needed.

With these algorithms the system can concern energy in occupied zones of the building and reduce energy in unoccupied zone. Appliances and multimedia devices consume energy even they are in stand-by. In a case of a TV, predictions can be used by activation of the power socket where is connected with the receiver, storage and audio system only when is the possibility that the occupant may arrive. On a large scale this can reduce important energy costs. This kind of implementation is for maximum energy economy and is where the initial automation implementation budget is large. Another example is room temperature prediction. The system knows when the occupants need to use a room (approximations from time schedule and database status values) and knows the response time of the heating/cooling system, so he knows when to turn on the heating/cooling unit.

This system also uses learning functions. He can learn user's temperature preferences and he can automatically set specific temperatures using a time schedule. Or users can set buttons functions by memorizing actual status of assigned actuators or relays. So they can simply interact with the system by setting their preferences.

Using data log the system knows occupants daily schedule and can predict the location where a possible intrusion can occur. For prevention concern on that zones and takes more scanning from the rooms using installed sensors. And he indicates these results on a screen for security agents if they exist.

Another tested algorithm is for safety. The system use prediction to know where and when a fire is possible to occur and that by data log appliances status.

A. Configuration of the WinCC Interface

WinCC is a powerful scalable engineering and runtime HMI application for use on Windows operating systems, which communicates with both the operator and the automation system.

With the WinCC Runtime software, the operator can run and monitor the process and the software has the following tasks: reading of the data stored in the CS database, displaying of the screens, communication with the automation systems, archiving of the current runtime data, such as process values and alarm events, current state of the process.

The basic components of the WinCC application are the configuration software and the runtime software. The WinCC Explorer is the core of the configuration software. In the WinCC Explorer, the entire project structure is displayed and the project is managed. To develop and configure projects, special editors are provided which can be accessed from the WinCC Explorer. With each editor, a specific subsystem of WinCC is configured. Using the runtime software, the operator can run and monitor the process.

To set up and test a new project these steps are required:

(1) Start SIMATIC WinCC Explorer;

(2) Create a new project;

(3) Select and install a communication driver – in our case Industrial Ethernet for communicating with the building field nodes;

(4) Define the building installations and devices tags;

(5) Create and edit the building systems and functions screens;

(6) Specify the WinCC runtime properties;

(7) Activate the building screens in WinCC Runtime;

(8) Use the WinCC Tag Simulator to test the building screens before implementing the hardware section.

A part of the of the Building Automation System main menu designed in WinCC Graphic Designer can be observed in Fig 2.

B. Communication, redundancy and multi-user systems

In the building automation system, as a SIMATIC environment, the WinCC communication peers are the central modules from PLC's and the communications processors from the computers/servers. These communicate with each other and exchange data. Maximum 32 WinCC clients can have access to the same redundant server project. The technology is "client without a project". All WinCC data is stored in the integrated Microsoft SQL Server database on the WinCC server and the WinCC clients do not have their own WinCC project.

The main two requirements of a WinCC server are:

WinCC/Server option;

Microsoft Windows Server/Advanced Server operating System.

Several technicians, building owners or employees can monitor a single installation, and each operator can see the manipulations performed by the other operators. The clients are distributed such that each one can monitor different views of the same process from the building and can monitor and control the same view of the installation from different locations (garden, exterior parts of the building, other buildings from the same automation system). The project can be configured and activated locally or remotely with full access from a WinCC client, which is also used as a maintenance PC.

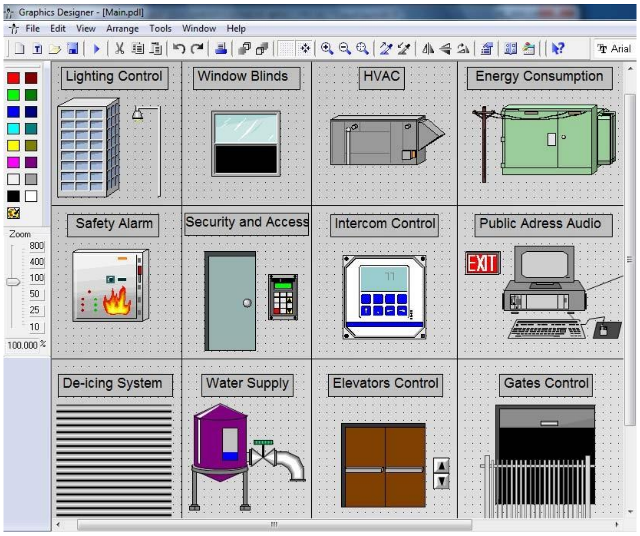

Figure 2. Part of the Building Automation System main menu

Alternatively, a separate dedicated configuration laptop (SIMATIC PG) can be used. For security reasons access rights can be specified for each user.

The client-server technology makes it possible to separate WinCC clients from the WinCC server. The project is configured on the WinCC server and then the clients are managed with their properties. The WinCC server interfaces with the building automation system and takes over the task of supplying the WinCC clients with the runtime environment, communication and coordination, processes pictures and values, messages, archive data and logs.

A WinCC project has special features like:

Process specifications or message acknowledgments on one client are available to the other clients;

The WinCC clients access data from the WinCC server, thus they can be connected to the system after the initial configuration;

A WinCC client can be installed without the Microsoft SQL Server database to comply with IT specifications;

In a multi-user system, a WinCC client always accesses one single WinCC server;

The multi-user project can be duplicated on a second, redundant WinCC server for system availability. For this WinCC/Redundancy option must be used. The option provides automatic database synchronization including client switchover;

The modular WinCC server technology can enable the following features on the multi-user system: a second redundant WinCC server, a separate long-term archive server, access to WinCC via the integrated OPC server.

C. *Advanced PC Configuration*

For commissioning PC stations as part of an industrial communication network Advanced PC Configuration was used. The configuration of an entire system can be created on one central computer which is the engineering system, or ES. With this system the consistency of the configuration and the building elements adaptation can be checked. Also the configuration can be distributed by the engineering system to the PLC's over a network. The SIMATIC PC Station is an object in a SIMATIC STEP 7 project. A PC station for OPC (Object Linking and Embedding for Process Control) operation consists of minimum two major elements: one or more communications modules and an OPC server application. Minimum one PLC is connected to an Ethernet network over which other communication partners can be reached. In our case all the communication partners are connected to an industrial Ethernet network. The OPC server must be included in the configuration because it uses communication services directly. OPC clients do not't need to be configured.

PC stations are distinct between applications like: Engineering Station used for both configuring the building automation system operated with S7 stations as well as for process control tasks, Run-time PC used for control tasks, PG/PC used for diagnostic and maintenance tasks.

For Commissioning and Configuring SIMATIC PC Stations next steps are necessary:

(1) Installing SIMATIC NET Software - first step for commissioning the PC stations is installing the SIMATIC NET software. When the SIMATIC NET software is installed, the following tools are available:

Commissioning Wizard that allows simple and consistent commissioning of the modules and user programs from the Advanced PC Configuration;

PC Station Wizard;

SIMATIC NCM PC Configuration Tool which is a new configuration tool for STEP 7;

Configuration Console which is a snap-in program embedded in the Microsoft Management Console (MMC) which provides a wide range of options for configuring PC hardware components and PC user programs. Configuration Console provides diagnostic functions and settings for the OPC servers.

Station Configuration Editor is the user interface of the Station Manager which allows the access to the component management of the PC station.

Configuration Information Service;

OPC Server;

OPC Scout.

(2) Installing the Hardware (PC modules)

(3) Starting up PC Modules for the First Time with the Commissioning Wizard - this initial configuration is necessary for newly installed modules, here a "virtual slot number" is assigned. To make the PC station ready to receive configuration data over the network, a station address and bus parameters must be specified during the initial configuration. The

information from the defined configuration can be transferred from the configuration system to the PC station, only if the local configuration match the configuration entered in the project configuration. Commissioning Wizard can be used to configure the mode in which the modules will be operated.

(4) Configuring the PC Station with the PC Station - the PC station and the network are configured in SIMATIC NCM PC or in SIMATIC STEP 7. The configuration consists in describing the automation system. This configuration is downloaded to the run-time system.

(5) Downloading Configuration Data to the PC Station - there are three possibilities for transferring a configuration to the PC station: network load, local load, and with a XDB file. To download the configuration data directly to a PC station attached to the building Ethernet network the online networked mode must be used. This option can be used only if these three requirements are fulfilled: a connection is present, the run-time PC is not the configuration station and the run-time PC is accessible as a communication node through the network.

(6) Entering/Creating Symbols - from SIMATIC NET variable names, known as symbols, can be specified. Also a hierarchical structure for the imported name space from an S7 device can be specified. A symbolic name space is created with the Symbol File Configurator tool. This software tool creates a file containing the symbolic hierarchical name space and the assigned run-time names.

(7) Checking the Configuration and Diagnostics - the "Configuration Console" tool starts automatically when the work with Commissioning Wizard is finished.

(8) Testing with the OPC Scout – if an OPC Server is used for the configuration, the functionality of the communications system must be tested.

IV. Hardware Testing Platform

For implementation of the redundant SCADA system two SIMATIC Rack PC 847B are used as servers and for the clients two SIMATIC Rack PC 647B. For testing platform two SIEMENS SIMATIC S7-300 PLC's are used, one S7-313 and one S7-314. PLC's take sequential pairs of the Building Automation System functions: Lighting Control, Window Blinds Control, HVAC, Energy Consumption Management System, Safety Alarm System, Security and Access Control, Intercom Control, Public Address Audio System Control, Deicing System, Water Supply and Irrigation System, Elevators Control and Gates Control. The system contains a SIMATIC PG laptop.

The PLC's are configured and programmed in STEP 7 version 5.5. STEP 7 is a standard SIEMENS software package, part of the SIMATIC industry software. An example of programming with STEP 7 is described in Fig. 3.

The Building Automation System Ethernet Network is implemented using four SCALANCE switches: X204-2 where the servers are connected, X206-1 where PLC1 and the SIMATIC PG are connected, one X208 where the Client 2 and the PLC 2 are connected and another X206-1 where Client 1 is connected. The connection between SCALANCE X208 and the two SCALANCE X206-1 is made using twisted pair cable. The connection between SCALANCE X204-2 and the two SCALANCE X206-1 is made using fiber optic. The connection between servers, clients, PLC's and SCALANCE switches is made using also twisted pair cables.

Redundant 10/100 Mbit/s ring topologies can be established via the SCALANCE X-200 switches. On the failure of a transmission link or a switch, the transmission path is reconfigured within 200 ms.

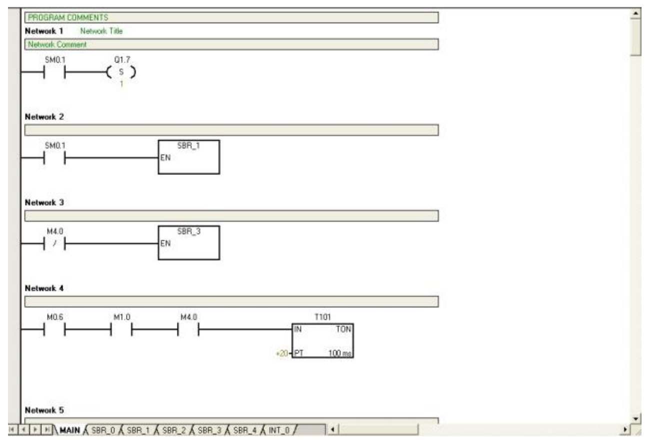

Figure 3. STEP 7 working steps

With the C-PLUG swap, devices can be exchanged without using a programming device; the configurations are stored on the C-PLUG and can be implemented in another SCALANCE X-200 switch. Based on PROFINET, the SCALANCE X-200 switches can be easily integrated into the Building Automation System Network. The implementation schematic of the hardware testing platform can be observed in Fig. 4.

The design of the Building Automation System testing platform is made in EPLAN Electric P8, property of EPLAN Software & Service GmbH & Co. KG, software which offers unlimited possibilities for project planning, documentation and management of automation projects.

An example of connecting a SIEMENS S7-300 digital outputs can be observed in Fig. 5 and the digital inputs can be seen in Fig. 6. Both examples are design with EPLAN Electric P8.

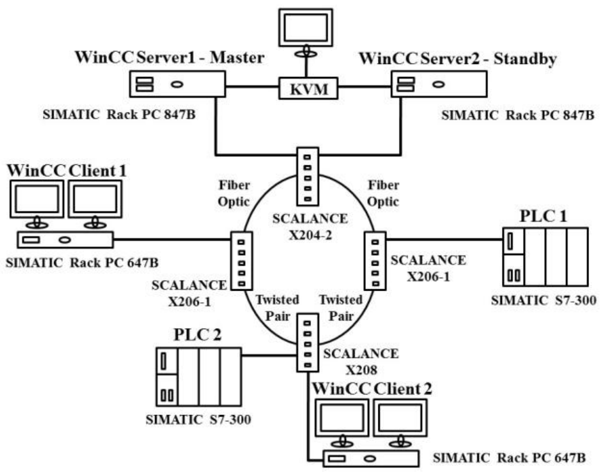

Figure 4. Hardware testing platform schematic

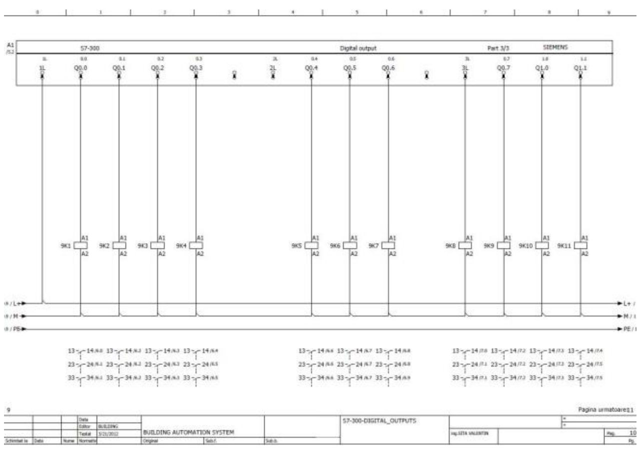

Figure 5. EPLAN Electric P8 design example: SIEMENS S7-300 digital output connections

V. CONCLUSIONS

A basic special functionality of these systems is an advanced technical surveillance. A technician can monitor all building systems using only one HMI device. Several technicians can monitor a single process or installation from the building, and each technician can see the manipulations performed by the other technicians. In this way they can communicate and collaborate for building maintenance and errors detection.

A benefic collaboration result from communication between technicians and building automation programmers through software reports.

Using prediction is good method for implementing building automation algorithms that are benefic for reducing energy consumption and simplifies people lives.

Using SIEMENS SIMATIC S7-300 PLC's local building real-time processes for building automation can be implemented, but the building automation system in general is not real-time.

Using multiple SIEMENS SIMATIC servers a redundant BAS can be implemented.

The system allows different implemented algorithms to be selected and on-line uploaded in PLC trough the Ethernet Network.

One important fact is that for extension must be choose equipments from the same producers and the new devices have to be compatible with the old ones.

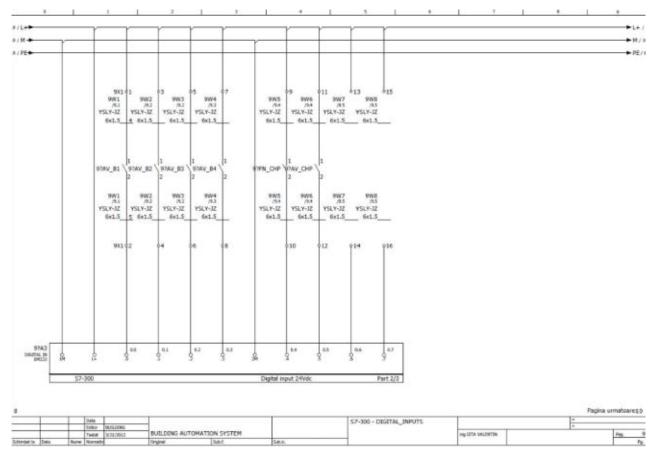

Figure 6. EPLAN Electric P8 design example: SIEMENS S7-300 digital input connections

REFERENCES

[1] Zhao Xiu-fen and Wang Hong-yu, "Application of WinCC Software to Building Automation System", 2010 International Conference on Future Power and Energy Engineering, pp. 19-21.

[2] Akio Orihara, Ken Nozaki, Nobuhisa Kobayashi, Masahiro Oguri, Shinobu Tajima and Masahiro Inoue, "An Autonomous Decentralized System Platform under Multi-vendor Environments in Building Automation", Proceedings of the 3rd International Symposium on Autonomous Decentralized Systems (ISADS'97), pp. 409-415.

[3] Michael LeMay, Jason J. Haas and Carl A. Gunter, "Collaborative Recommender Systems for Building Automation", Proceedings of the 42nd Hawaii International Conference on System Sciences, 2009, pp. 1-10.

[4] ***SIMATIC HMI WinCC V7.0, System Description, 09/2008, A1900L531-B996-X-7600, SIEMENS AG, 5-52.

[5] ***Industrial Ethernet Switching, November 2008, SIEMENS AG.

[6] Hans Berger, "Automating with STEP 7 in LAD and FBD: SIMATIC S7300/400 Programmable Controllers", 4th edition, Siemens Aktiengesellschaft, Berlin and Munich, 2008, 1-32.

[7] ***SIMATIC Ladder Logic (LAD) for S7-300 and S7-400 Programming, Reference Manual, 03/2006, A5E00706949-01, SIEMENS AG, 1-228.

[8] ***SIMATIC System software for S7-300/400 System and Standard Functions, Reference Manual, 01/2004, A5E00261410-01, SIEMENS AG, 1-658.

[9] ***SIMATIC NET Commissioning PC Stations, Manual / Quick Start for SIMATIC NCM PC / STEP 7, 11/2002, C79000-G8976-C156-03, SIEMENS AG, 14-111.

[10] ***SIMATIC Configuring Hardware and Communication Connections STEP 7, Manual, 03/2006, A5E00706939-01, SIEMENS AG, 15-33.

[11] ***SIMATIC NET PROFIBUS Networks, Manual, 05/2000, 6GK19705CA20-0AA1, Release 2, SIEMENS AG, 41-67.

[12] ***SIMATIC Open TCP/IP Communication via Industrial Ethernet, Manual, 12/2005, A5E00711636-01, SIEMENS AG, 5-43.

[13] ***SIMATIC NET NCM for Industrial Ethernet, Manual for NCM S7, 12/2001, C79000-G8976-C129, Release 05, SIEMENS AG, 13-127.

[14] ***SIMATIC NET Industrial Communication with PG/PC, Manual, 05/2003, C79000-G8976-C172, Edition 02, SIEMENS AG, 29-149.