

# Supervisory Control and Data Acquisition Laboratory

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**Abstract** — This paper presents practical laboratory set in Supervisory Control and Data Acquisition (SCADA) systems. Practical labs introduce gradually the main SCADA elements and develop an application to control an induction motor in interlocked manual/automatic mode, with touch-screen Human Machine Interface (HMI). The SCADA concepts are implemented on an integrated automation system with distributed periphery using Democase from Siemens. The system illustrates trends, alarms, motor frequency and automatic sequence of motor speed profile.

**Keywords** — Automatic control, engineering education, Ethernet, hardware configuration, laboratory works, Profibus, programmable logic controller (PLC), supervisory control and data acquisition (SCADA), WinCC Flexible.

## I. INTRODUCTION

SCADA systems became popular to arise the efficient monitoring and control of distributed remote equipments. Today SCADA systems include operator-level software applications for viewing, supervising and troubleshooting local machines and process activities. Powerful software technologies are used for controlling and monitoring equipments in easy-to-use web-based applications, e.g., platforms: PCS7 – Siemens, CX-Supervisor – Omron, Genesis 32 – ICONIX [1].

The term *supervisory control* is associated with (i) the process industries, where it manages the activities of a number of integrated operation units to achieve certain economic objectives for process; and with (ii) the discrete manufacturing automation, where it coordinates the activities of several interacting pieces of equipment in a manufacturing cells or systems, such as a machines interconnected group by a material handling system [2]. SCADA networks contain computers and applications that perform key functions in providing essential services and commodities (e.g., electricity, natural gas, gasoline, water, waste treatment, transportation) [3]. They require the use of sophisticated automation schemes that must be able to grant access to production data and field distributed variables at large distances, and from various levels of factory automation (field, control, supervision, etc.) [4].

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*Programmable logic controllers* (PLCs) are used for system control. As need to monitor and control more devices in the plant grew, the PLCs are distributed and the systems became more intelligent and smaller in size.

In a *distributed control system* (DCS), the data acquisition and control functions are performed by a number of distributed microprocessor-based units situated near to controlled devices or by instruments from which data are gathered. DCS have evolved into systems, providing very sophisticated analog control capability [5].

SCADA, PLC and DCS are three types of control systems. Nowadays, there are systems that incorporate all these concepts in one integrated automation system.

This paper introduces theoretical and practical concepts regarding SCADA for education purpose, illustrated and implemented on an integrated automation system Totally Integrated Automation (TIA) from Siemens. Laboratory works will provide for student: competences, experience in identification, selection and programming of needed equipments to make a fully operational application.

The application includes control of an induction motor associated with a frequency inverter in manual or automatic mode. The manual control mode is equivalent to predefine frequencies and logic programming which are sent as telegrams to the frequency inverter. In the automatic control mode a specific sequence is run (sequential discrete control).

## II. PRACTICAL LABS FOR SCADA SYSTEMS USING TIA DEMOCASE

The development platform for applications is STEP 7, which is the standard software package, used for configuring and programming SIMATIC programmable logic controllers.

To create an automation solution with STEP 7, there are a series of basic tasks:

- Plan your controller;
- Design the program structure;
- Create a project structure;
- Configure hardware;
- Configure networks & communication connections;
- Define symbols;
- Create the program;
- Configure operator control and monitoring variables
- Download programs to the programmable controller;
- Test programs;
- Monitor operation, diagnose hardware;
- Document the application.

Following these steps, through practical labs, the students will learn to use the equipment and program it, and the final result will be an application for controlling an induction motor. Each practical lab has the following structure: *purpose, theoretical topics, workflow, questions and references.*

The gradual laboratory sections are structured as: A) General description of SCADA – TIA Democase, B) Hardware configuration and programming languages, C) Programming and commissioning for frequency inverter SINAMICS G120, D) Manual control for frequency inverter, E) Automatic control for frequency inverter, F) Integration of manual and automatic control modes for frequency inverter, G) Programming elements in WinCC Flexible.

*A. General Description of SCADA - Totally Integrated Automation Democase*

The aim of this section is to present the SCADA system with its components. SCADA - TIA Democase from Siemens (Fig. 1) is an integrated automation system for digital control of electric drives with distributed peripheral [5]. It can be used for a wide range of applications with variable speed drives, like: pumps, fans or conveyor belt, etc.

The used TIA Democase components are (Fig. 2):

- S7-300 PLC that controls ET200S;
- ET200S consists on: communication interface module IM 151-3, Motor starter DS1e-xH, proximity sensor Opto Bero;
- Sinamics G120 frequency inverter;
- induction motor connected via PROFIBUS;
- Human Machine Interface (HMI) panel MP 277 connected via industrial Ethernet.

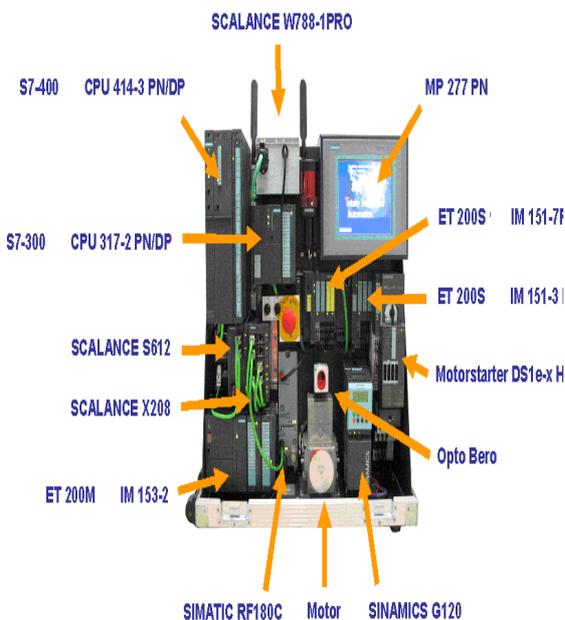


Fig. 1. SCADA – TIA Democase setup.

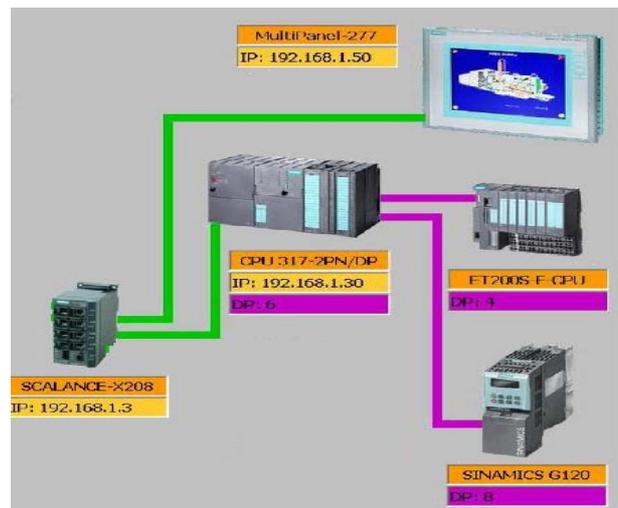


Fig. 2. Components of SCADA – TIA Democase.

*B. Hardware Configuration and Programming Languages*

This section presents concepts on how to configure the hardware, the communication connections and some programming elements. In Fig. 2 are presented the used components for the application.

*Hardware Configuration* is a tool used to configure and assign parameters to the hardware of an automation project. In this session, the students learn how to configure the PLC and its input–output modules properly. The students are required to develop simple programs using *the Ladder Diagram Language*. LAD will be used to design the control logic for the manual drive control.

*S7Graph* is used to structure a sequential program resulting in implementation of automatic drive control. [7] *WinCC Flexible* is employed as SCADA platform.

At the end of this section, the hardware configuration for the application and some short examples using the programming languages will be implemented by students.

*C. Programming and Commissioning for Frequency Inverter SINAMICS G120*

This section presents the frequency inverter SINAMICS G120, its parameters and telegrams and the software (STARTER) used for drive/commissioning.

The inverter is parameterized to be adapted to motor for optimal operation and protection. This is realized using one of the following operator units:

- Keyboard and display unit (Operator Panel) that is snapped onto the inverter;
- Software (STARTER commissioning tool) that allows the inverter to be parameterized and controlled by a PC.

Inverters can be parameterized for very specific applications; many of them can be configured by means of just a few parameters [8]. The specific telegrams are understood and developed. As a workflow for the section, a LAD program (Fig. 3) will be implemented for the following functionalities: motor off, motor on, start motor at a preset frequency (25Hz), reverse sense, initialize the system (start direct starter, motor off, frequency 0 Hz).

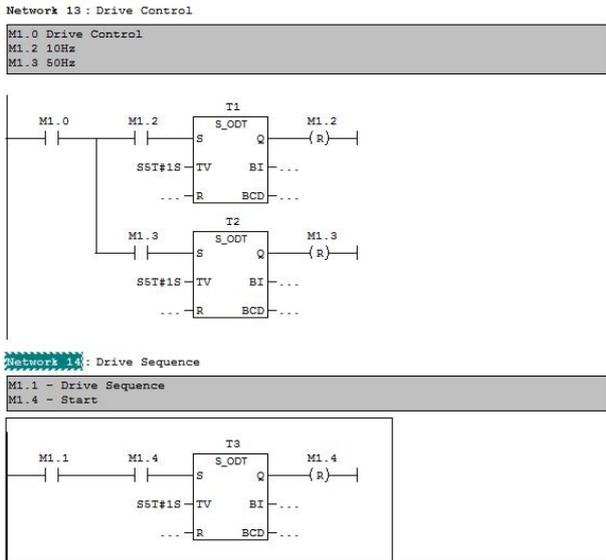


Fig. 3. LAD program for inverter control.

**D. Manual Control for Frequency Inverter**

The aim of this section is to implement the manual drive control for the frequency inverter. The manual operating mode for the motor assumes the following:

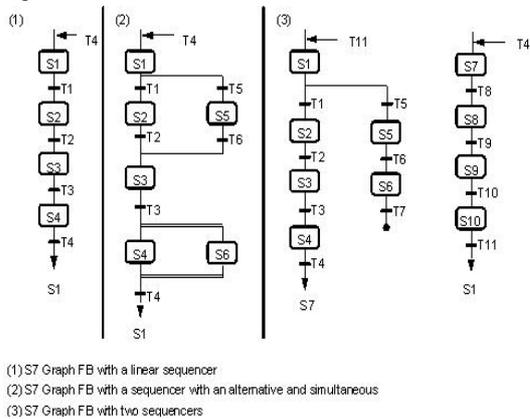
- Start the motor at preset frequency (10, 25 and 50 Hz);
- Stop the motor.

The three-phase induction motor is controlled by the inverter. The motor starter will protect and switch any three-phase loads. The ensemble formed by ET200S (Direct starter), inverter and motor have to be programmed. For programming the inverter, telegrams will be sent to it. In the hardware configuration for SINAMICS G120, the standard telegram 1 was selected.

Ladder logic LAD is used for programming the manual drive control [8].

**E. Automatic Control for Frequency Inverter**

This section main scope is the implementation of automatic control of the frequency inverter used for controlling the induction motor. The automatic control consists in a sequence of steps executed in a defined order. A sequencer consists of a series of steps and transitions that are activated in a fixed order depending on the step enabling conditions.



(1) S7 Graph FB with a linear sequencer  
 (2) S7 Graph FB with a sequencer with an alternative and simultaneous  
 (3) S7 Graph FB with two sequencers

Fig. 4. Sequencer types in S7 Graph.

In Fig. 4 are presented a few usual sequencer types in S7 Graph: linear sequencer, alternative and simultaneous sequencer and parallel sequencer.

The following sequence will be designed:

- Step 1 – Run at 10Hz,
- Step 2 – Hold for 10s 10Hz,
- Step 3 – Run at 25Hz,
- Step 4 – Hold for 10s 25 Hz,
- Step 5 – Slow down to 10 Hz,
- Step 6 – Hold for 10s 10Hz,
- Step 7 – Ramp up to 50Hz,
- Step 8 – Hold 50Hz for 10s,
- Step 9 – Reverse rotation sense to -50Hz,
- Step 10 – Hold -50Hz for 10s,
- Step 11 – Slow down to 0 Hz,
- Step 12 – Stop

**F. Integration of Manual and Automatic Control Modes for Frequency Inverter**

This section presents the integration of the two inverter functioning modes (Fig. 5). The subsystems have to cooperate so that the system is able to deliver the overarching functionality.

- In this case, there are a series of conditions to consider:
- The switching between the two subsystems (operating modes of the inverter) is possible at any time;
- A force stop is available in each subsystem, when the inverter brings the motor in its initial state.

Only in the manual control mode, the proximity sensor is on. When the IQ-Sense module detects an object, the motor is stopped and the motor starter is disabled (contactor off). In this case, an initialization is necessary to start running again the application [9].

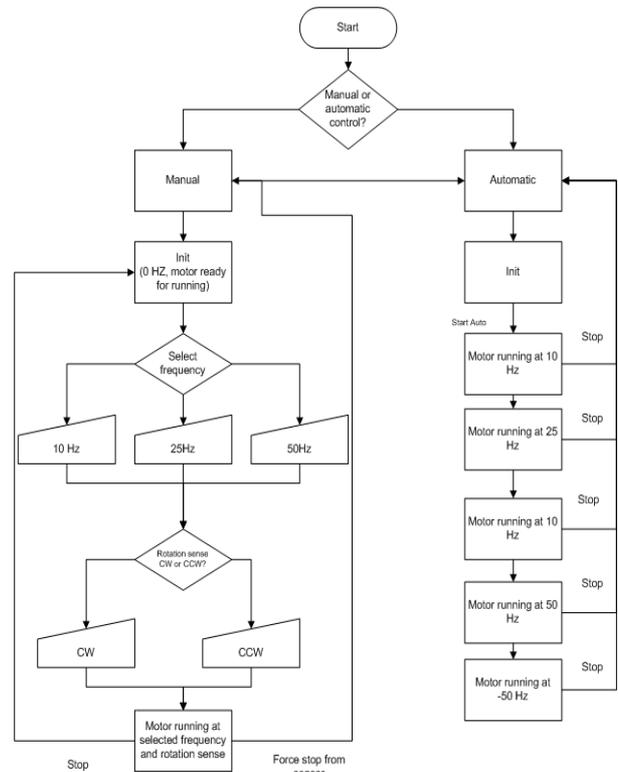


Fig. 5. Flowchart of Man/Auto control modes.

### G. Programming Elements in WinCC Flexible

This section:

- Introduces WinCC Flexible - the software for programming the HMI in SCADA applications
- Presents some special objects: trend view, gauge, alarms, scripting [8]
- Finalizes the main application.

Process tags provide the link for communication between the controller and HMI system.

The workflow for this practical lab is the following:

- Create the connection between the PLC and HMI, define all necessary tags and assign them to buttons.
- Create a script to convert the frequency value from hex to decimal, and associate the value to an internal tag.
- Insert into the manual drive control a gauge for the frequency value (Fig. 6).
- Create a screen for automatic drive control (Fig. 7).
- Create a trend view to monitor the frequency (Fig. 8).
- Create two analog alarms:  $f < 25$  Hz and  $f > 45$  Hz.
- Create discrete alarms to notify when the frequency is at 10 Hz, 25 Hz and 50 Hz.
- Create a screen for the alarm view
- Insert buttons in both operating modes for trend view and alarms.
- Finalize the application.

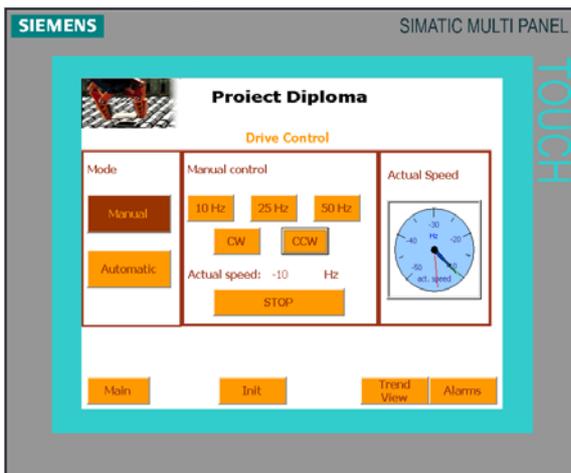


Fig. 6. Manual drive control mode.

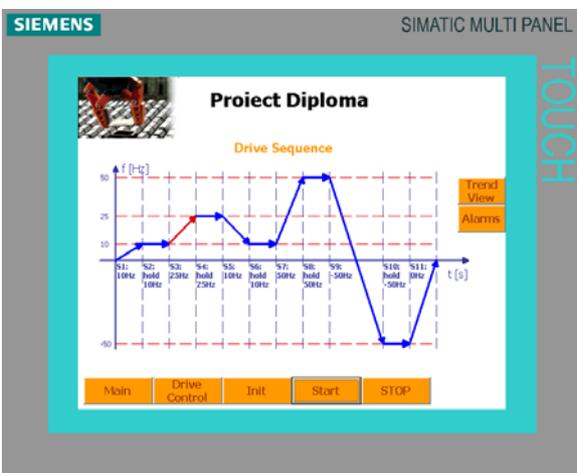


Fig. 7. Auto drive control mode-reference sequence.

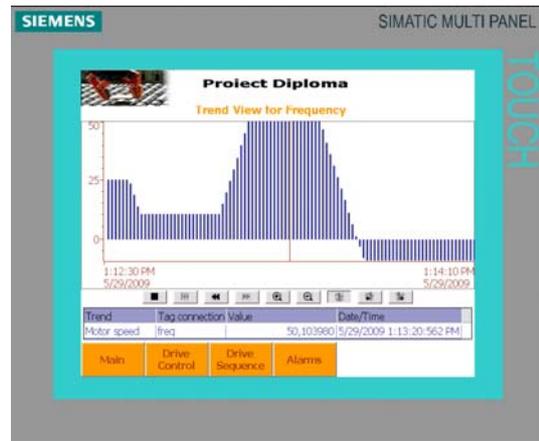


Fig. 8. Trend view for inverter frequency.

### III. CONCLUSION

This paper deals with theoretical and practical concepts for student education purpose in Supervisory Control and Data Acquisition (SCADA) systems. The laboratory work package is focused to gradually develop applications using an integrated automation system from Siemens with distributed peripheral employing Profibus and Ethernet communications. The final application is targeted to control an induction motor with associated frequency inverter, in interlocked manual/automatic mode, with touch-screen HMI interface, to program the motor speed and to show variables, trends and alarms.

The application was divided into seven sections with specific activities, progressively developed as a good example of an automation problem solved following the basic steps necessary for an accurate industrial solution.

One of the SCADA labs goals is to help students in developing skills necessary to design and analyze professional automatic control systems in process, plant and manufacturing technology engineering.

The concepts and software technologies used to develop the present application can be reused to write many other similar control/supervisory applications.

### REFERENCES

- [1] M. Iacob, G.-D. Andreescu, and N. Muntean, "SCADA system for a central heating and power plant," in *Proc. 5<sup>th</sup> International Symposium on Applied Computational Intelligence and Informatics SACI 2009*, Timisoara, Romania, May 2009, pp. 159–164.
- [2] M. P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, 3<sup>rd</sup> Ed., Pearson Education Inc., Prentice Hall, 2008.
- [3] A. Kalam and A. Zayegh, "Network security vulnerabilities in SCADA and EMS," *2005 IEEE/PES Transmission and Distribution Conf. and Exhibition: ASIA and PACIFIC*, Dalian, China, 2005.
- [4] F. Adamo, F. Attivissimo, G. Cavone, and N. Giaquinto, "SCADA/HMI systems in advanced educational courses," *IEEE Transactions on Instrumentation and Measurement*, vol. 56, no. 1, pp. 4–10, Feb. 2007.
- [5] D. Bailey and E. Wright, *Practical SCADA for Industry*, Newnes Elsevier, 2003.
- [6] *TIA Democase Anhang C-Komponenten des TIA-Demokoffers.doc*, 2007.
- [7] O. G. Bellmunt, D. M. Miracle, S. G. Arellano, A. Sumper, and A. S. Andreu, "A distance PLC programming course employing a remote laboratory based on a flexible manufacturing cell," *IEEE Transactions on Education*, vol. 49, no. 2, May 2006.
- [8] Siemens, *SINAMICS G120 CU240S and CU240E Control Units, FW 3.2 Operating Instructions CU240S and CU240E Control Units, FW\_3.2\_enUs.pdf*, 2009.
- [9] *Siemens WinCC Flexible Help Manual*, 2006.