# Contribution to the Study and Realization of a Control-Command System of an Electrical Network for Isolated Sites

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**Abstract** This article presents experimental work on the optimal management of energy generated in power grids. The goal is to build a data acquisition program with TIA automation software that reduces the power consumption of a power plant or company. To this end, a Supervisory and Data Acquisition System (SCADA) was realized and its application was carried out on the electrical installations of the Laboratory of Automation, Electronics, Electrical Engineering and Industrial Computing (LA2EI) of the Faculty of Sciences and Technology (FAST). The layouts of the electrical installations of the three (3) rooms of the laboratory were identified before being implemented in the control-command program. The user can supervise the whole system by a touch screen (human-machine interface) or a laptop (PC) thanks to the PLC and the DIRIS A40. It involves setting up a control system that can reduce operator errors, increase security and access to information in real time. The program was later validated by its application in the laboratory research room.

**Keywords** SCADA, electrical networks, programmable logic controllers, human-machine interfaces.

## 1. Introduction

Energy is involved in all human activity and is essential to the satisfaction of many daily needs namely water supply, food or health. Thus, to fight effectively against poverty, it is essential that people have access to electricity. Under the dual effect of economic growth and population growth, the International Energy Agency (IEA) projects an increase in global electricity needs of 55% between 2005 and 2030 [1, 2, 4]. It will therefore be necessary for researchers and industrialists to put in place systems capable of rigorously and efficiently managing electrical energy [5, 6]. The quality control of power grids and the monitoring of data acquisition systems in modern industry have become increasingly important in recent decades [3, 7, 8, 9, 10, 11, 12, 13]. It is therefore interesting and even essential for power system operators to have the means to control critical quantities such as reactive powers, voltages and power transits in the lines so that the electricity networks can be operated in a manner and safe. This work also falls within the framework of energy efficiency because it is part of the economisassions of electric energy and access for all [14].

## 2. Materials and methods

### 2.1. Summary presentation of the study site

The laboratory LA2EI (Figure 1), located in the grounds of the Faculty of Sciences and Technology of Abdou Moumouni University of Niamey, includes three rooms: the room Automation and Industrial Computing (A2I), the room Electronics and Electrical Engineering (EE) and Research Room (R). The Automatics and Industrial Computer Room (A2I) is used for the courses of Automatic, Industrial Computer Science, and Practical Work

(TP) students. That of Electronics and Electrical Engineering welcomes students for the practical work of Electronics and Electrical Engineering. The research room, as its name suggests, is for research work.



*Figure 1: Photo of LA2EI laboratory building*

## 2.2. Table of general distribution of the laboratory

On this general distribution table, the numbers from 1 to 13 represent the circuit-breakers room A2I and the symbol R the circuit-breaker of room R.
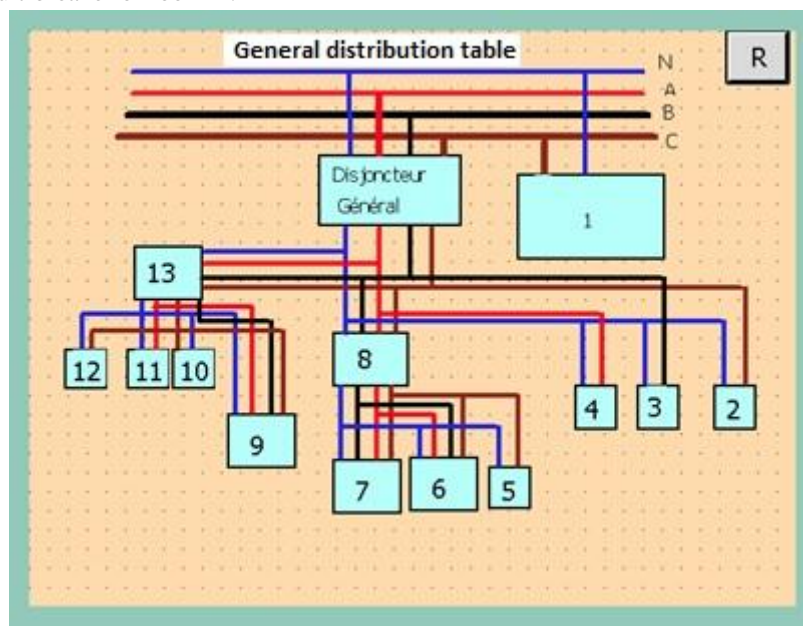


*Figure 2 : Diagram of the general distribution table*

## 2.3. Functional diagram of the LA2EI SCADA system

The functional diagram of the LA2EI SCADA system consists of the following equipment: DIRIS A40, PLC, computer, HMI and router. It is necessary to allocate IP addresses to all hardware. As these devices are on a local internet network, you must also configure the router to make it accessible to this network. Figure 3 shows the configuration of IP addresses and MAC addresses for the devices used.
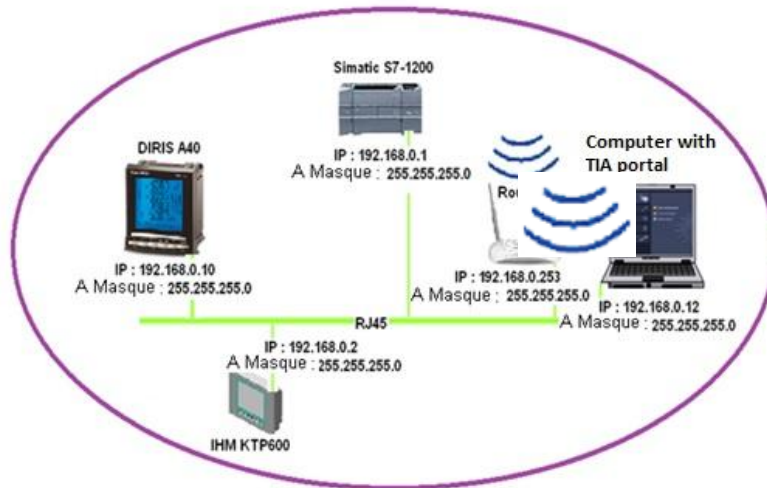
*Figure 3 : Functional diagram of the SCADA system of the LA2EI laboratory*

### 2.4. The control part of the SCADA of LA2EI

The control part (Figure 4) serves to control the operation of the automated system; it consists of:

• input interfaces (electronic discrete input modules, analog modules, automation relays, etc.),

• output interfaces (electronic discrete output modules, analog modules, automation relays, etc.),

• processing systems (automation relay, electronic processor modules) and communication systems (communication modules),

• man-machine interfaces (lights, buttons, screens ...),

• electrical energy distribution systems (230VAC / 24VDC power supplies, cables, circuit breakers, etc.),

• special modules (vision, contactless identification).

The SCADA program of the LA2EI electrical circuit control is loaded into the programmable logic controller (CPU). We have programmed the circuit breaker (the general circuit breaker of the LA2EI laboratory and / or the three laboratory rooms) so that the control is manual or automatic.

Figure 4 shows the photo of the SCADA control facility of the LA2EI laboratory. In this figure, the numbers from 1 to 6 represent respectively the sensor, the RJ45 cable, the thermal relay, the 220 \ 24 \ 12V transformer, the contactor and the Simatic S7-1200.
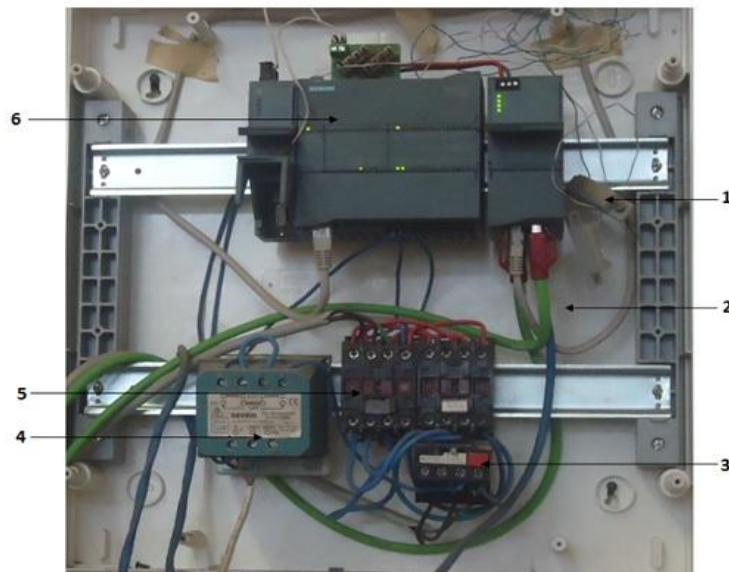


*Figure 4: Photo of the control installation*

### 3. Results and Discussions

To operate the SCADA system, we have developed a computer program using the TIA Portal automation software.

We then linked on an Internet network all the equipment used in the realization of the SCADA (figure 5). To control the installations of the LA2EI SCADA, we realized the single-line diagram of the electrical circuit of the laboratory, of all the electrical sockets and the multi-wire diagram of the electrical circuit of each room of the laboratory. After the development of the various SCADA circuits of the LA2EI laboratory, we proceeded to the phase of control and measurements of the electrical quantities in order to evaluate the electricity consumption of the laboratory. This process is carried out according to the following steps: measurements in room R, room A2I, room EE, and finally acquisition and processing of data. In FIG. 5, the numbers from 1 to 10 are assigned to the following devices: 1: control part, 2: power circuit breakers, 3: the inverter, 4: the computer screen with TIA Portal, 5: the stabilized power supply, 6: the central unit, 7: the KTP600 Human Machine Interface (HMI), 8: the router, 9: the 220/110 transformer and 10: the DIRIS A40.



*Figure 5: Photo of SCADA control-command*

In the computer program, we created five subprograms (network):

Network 1 activates the circuit breaker control, after a time that we set at 3 seconds (T # 3S). The start mode (Automatic / Manual) is done using the sensors. The timer is installed for security reasons. This delay makes it possible to give a dead time of securing devices before triggering the command.

Network 2 activates the circuit breaker control in "Automatic" mode or in "Manual" mode. This network allows the switching of the manual or automatic control.

Network 3 activates the control in "Manual" mode only.

Network 4 activates the control in "Automatic" mode only.

The network 5 activates the central breaker stop whatever the mode of operation (automatic or manual). It is also possible to shut down the entire system by pressing the "emergency stop" button on the circuit breaker.

Figure 6 shows the view of the switch (pushbuttons) on the tested SCADA control panel. The top push button is the command button and the bottom push button is the off button. The box containing the "0" of the top is linked by the computer network to the button of the command: it takes the value 1 when the button is pressed (state of on); it takes the value 0 when the circuit is open. This is the same principle for the one containing the "0" from

below which is linked to the stop switch. The icon "1" represents the view of Figure 7 (view 1). To access this view, double click on this icon.



*Figure 6: View of SCADA control buttons (view R)*

Since the Human Machine Interface (HMI) can create multiple views, we have made several configurations. As soon as you enter the program, you will see in turn:

- the root view (Figure 6),
- the view 2 and 3, for the measurement of the various parameters of the laboratory circuit,
- the view 6, for access to the network A2I room (see Figure 8),
- the view 7, for access to the network of the room R (see Figure 10),
- the view 8, for access to the network of the EE room (see Figure 9),
- the view 9, for access to the general LA2EI distribution scheme (see figure 2).

View icons make it easier to switch from one view to another. Thus, from the root view (view R, figure 7), to access the circuits of the three rooms and the buttons of the command, just click twice on the icons "8" (room EE), "6" (Room A2I) and "7" (Room R) of Figure 7.
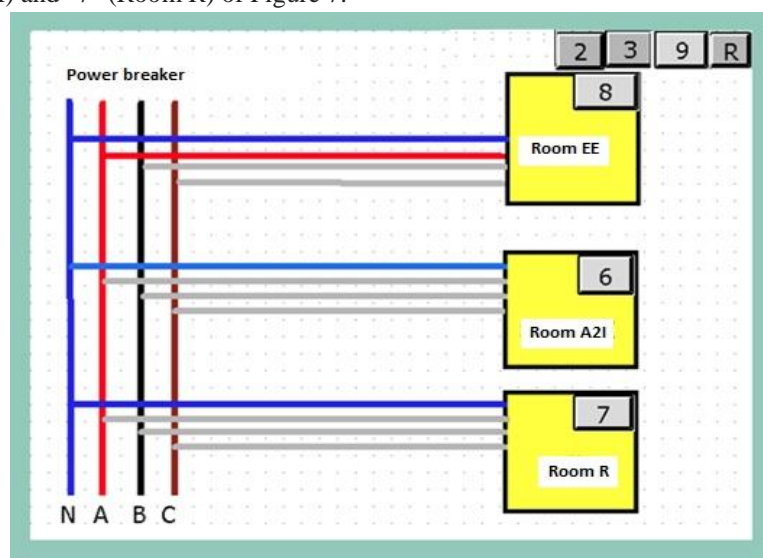


*Figure 7: The different views created (view 1)*

To return to the root view "R" (or control view), from Figure 7, we press R. So the passage of one window to another is simply by clicking on the corresponding icon. In Figure 7, the phase A (line 1) is represented by the red color, the phase B (line 2) is symbolized by the black color, the phase C (line 3) by the color brown and the neutral by the color blue.

The supply circuit breaker at the end of the laboratory network is either the main power circuit breaker or the room power circuit breaker EE, A2I or R. The symbol R represents the root view. The number 9 represents the view of the general pattern of LA2EI distribution (Figure 2). The numbers 2 and 3 represent the view for the measurement of the various parameters of the electrical circuit of the laboratory.

The control-command diagram of the automation and industrial computing room represents the modeling of the control and control of the electrical circuit of the latter. ? In this diagram, the current, the voltage, the power, the frequency at the arrival of each phase of the network are modeled on the left. The values of the simple and compound voltages are shown in Figure 8. The values provided by the NIGELEC power grid are shown on the left-hand side of the figure. ON and OFF buttons are modeled for each line and for the neutral. The transition from ON (start) to OFF (stop) is done by respectively pressing the ON and OFF button switch of Figure 8. The current is switched when the button is ON; the line takes its color (red, black, blue or brown) at the exit. When the button is ON, the line turns gray on exit; and the electrical quantities will be read on the DIRIS A40. The color of the neutral is identical whatever the ON or OFF state simply because it is not powered by electricity. All these LA2EI control-command diagrams are based on the WINCC flexible environment of the SIMATIC HMI. It should be noted that the plugs represent the power outlets of LA2EI. The principle is the same for the other control-command schemes of the laboratory.
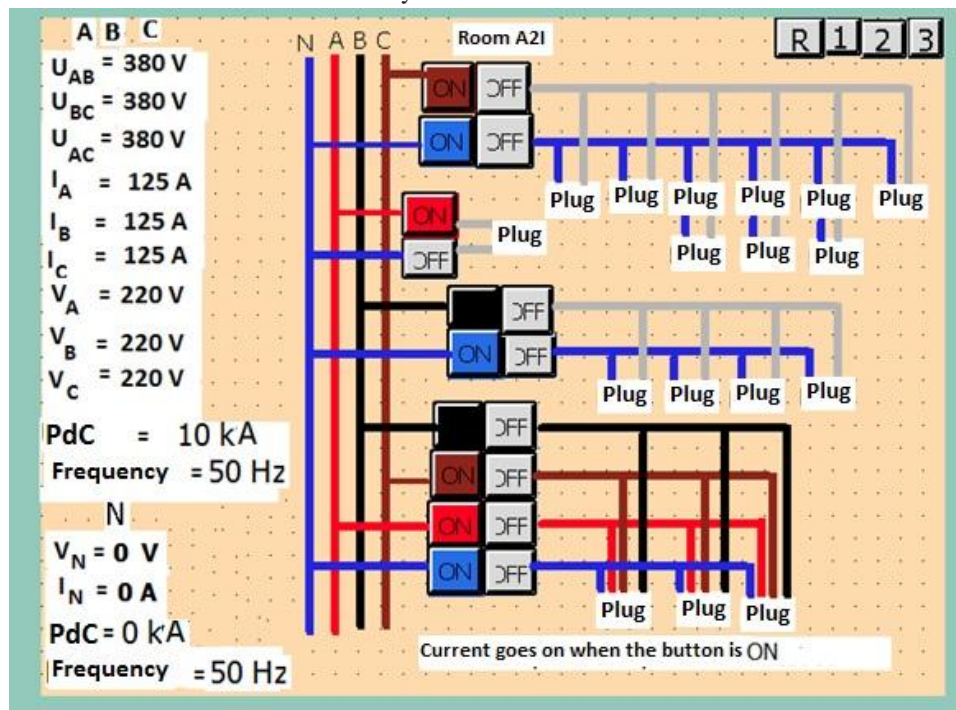


*Figure 8 : Control-command schema (view 6)*

The quantities $U_{AB}$, $U_{BC}$, $U_{AC}$ are the voltages composed (voltage between two phases) of the LA2EI network. The quantities $V_A$, $V_B$, $V_C$ are the simple voltages (voltage between phase and neutral) of the network. $I_A$, $I_B$, $I_C$, are the nominal currents of the main circuit breaker. $V_N$, $I_N$ are, respectively, the nominal voltage and current of the neutral. PdC is the breaking capacity of the circuit-breaker (the breaking capacity of a circuit-breaker indicates the maximum current for which the circuit-breaker interrupts the power supply.) It is the international standard IEC 947-2 which defines the PdC of the circuit-breaker (circuit breaker). The indicated frequency is the working frequency of the NIGELEC network (50 Hz). We have a voltage between a phase and the neutral (single voltage) at the single-phase sockets ($I_N = 0A$, $I_A$ or $I_B$, $I_C = 16A$ and $V_A$ or $V_B$, $V_C = 250V$). For three-

phase sockets, we will have a compound voltage that is to say the voltage between two phases ($U_{AB} = U_{BC} = U_{AC} = 380V$ and $I_A = I_B = I_C = 16A$).

The control-command principle of the other rooms is identical to that of the Automation and Industrial Computer Room (A2I). Figures 9 and 10 respectively show the control-command scheme of the EE room and the room R:
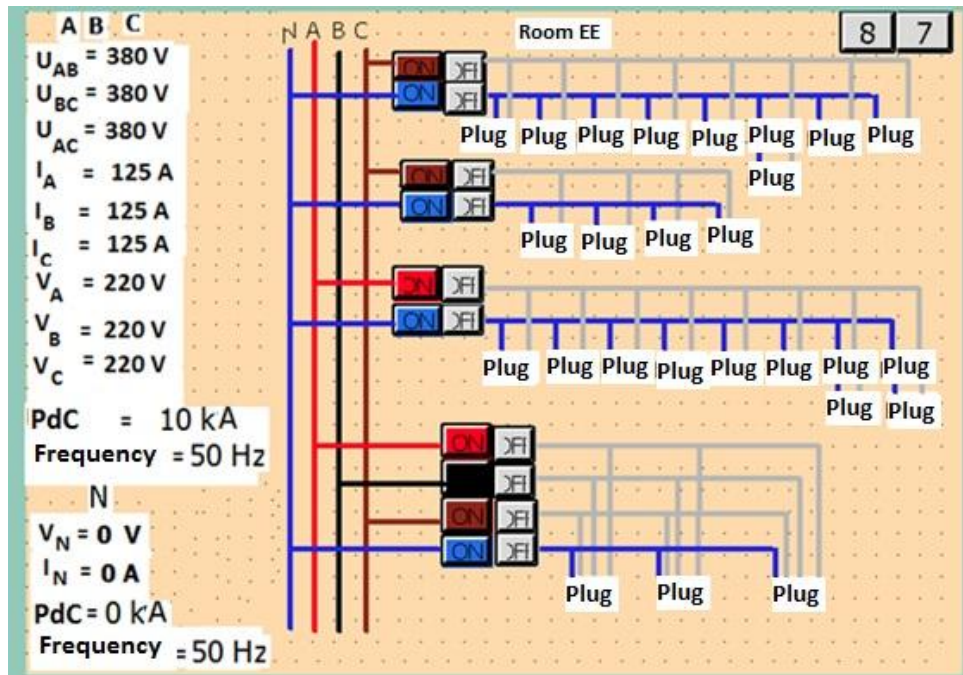


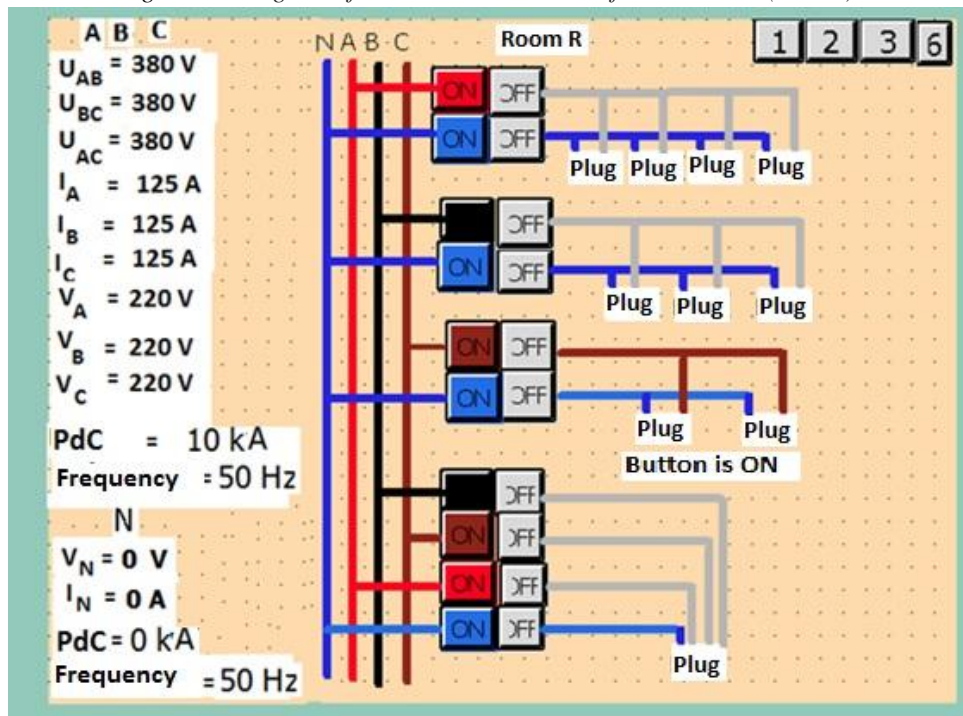*Figure 9 : Diagram of the control-command of the EE room (view 8)*



*Figure 10 : Diagram of the control-command of the room R (view 7)*

**Test of the control program on the research room**

To test and validate the SCADA program of the LA2EI laboratory in the HMI panel, we first load the different SCADA views of each laboratory part into the panel. This is the automatic control that represents the control of the SCADA for the panel. The SCADA is tested on the circuit of the research room. We proceed as follows:

- we first press the push button (switch) at the top of the root view (Figure 6) to trip the circuit breaker. Once the circuit breaker is tripped, the current flows:
- then, to stop the flow of current we press the push button from below this same root view "R",
- the research room circuit breaker is programmed to be in emergency stop for the operation of this SCADA.

To obtain control results for all loads connected to the electricity grid, we connected the computer using the on-board web of the datalogger (the DIRIS A40). This internet network covers a radius of at least 150 m (Figure 11). This monitoring makes it possible to control all electrical quantities. It also makes it possible to detect all electrical faults (harmonic rate, reactive power problem) and other faults such as electrical overloads in order to balance the different loads on the electrical network (this load balancing between the phases will avoid the overload problem).
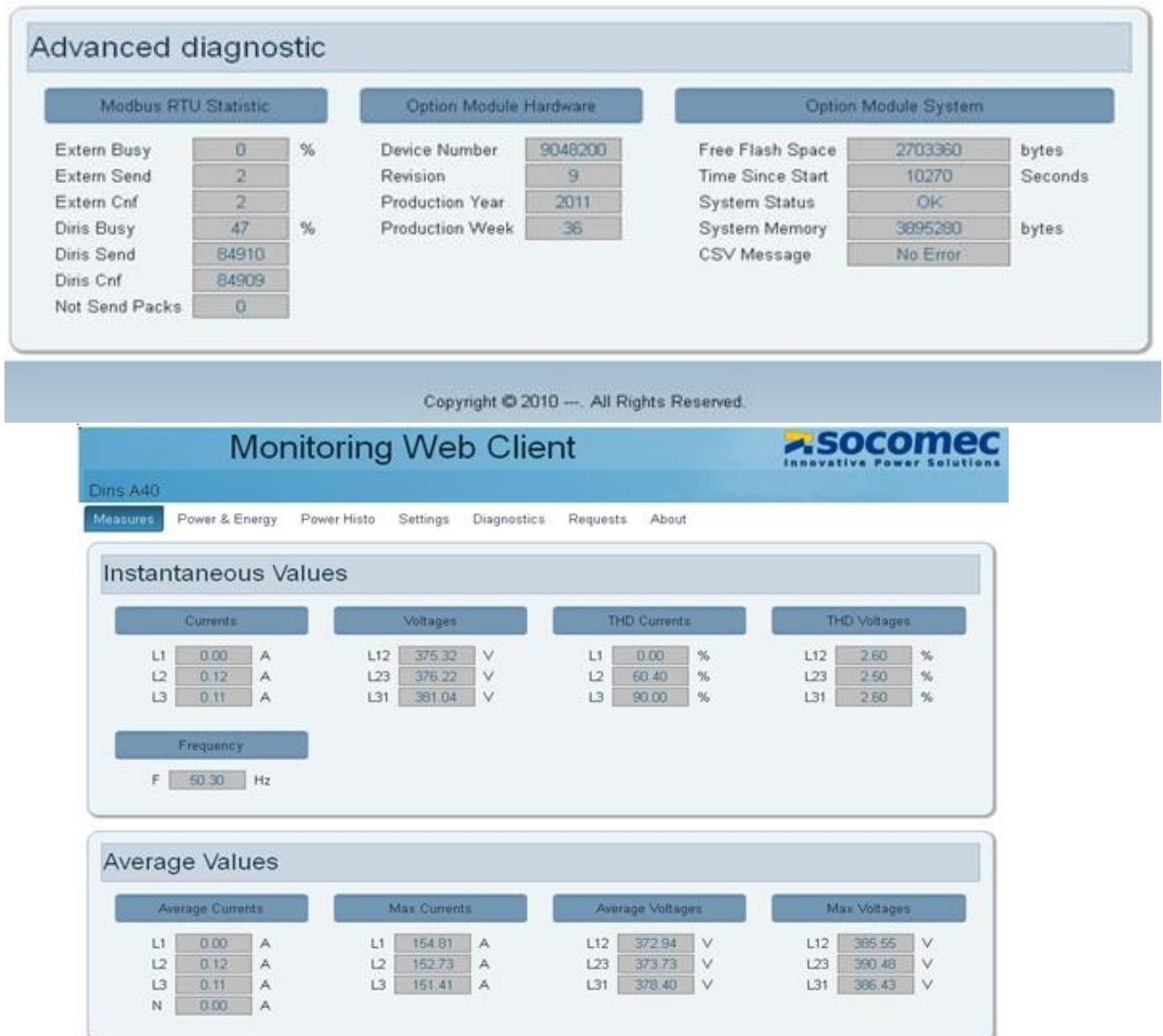


*Figure 11: Viewing the electrical measurements of the DIRIS A40 on the computer screen.*

Figure 12 shows the diagram of the circuit of the research room on which the test was made.

*Figure 12: Figure of the SCADA test in the HMI panel of the Research Room*

## 4. Conclusion

In this article, the computer program of the supervisory and data acquisition system (SCADA) was realized with the TIA software. It was then loaded into the programmable logic controller (CPU) and the Human Machine Interface (HMI) panel. The LA2EI power network circuit has been identified by the PLC and the various control-command diagrams of the laboratory are modeled, in order to display the real operating status of the electrical installations. The control-command of this SCADA was tested with the panel by the automatic control and the manual control by the CPU on the electrical network of the research room. The results of the SCADA trial on the research hall circuit were in good agreement with the results expected by the computer program. The experimental tests allowed to validate the control-program realized and the access to the information in real time. In perspective, it would be very interesting to apply control-command systems (SCADA) to the large-scale electricity networks of large cities, in order to control and optimize electricity consumption and access to electricity real time information.

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