CHAPTER 2: OBJECTIVES

The main goal of this project is to enable access to the laboratory of the power quality to the students. To have an option to study the deformation of the power supply due to different electrical devices connected into the supply network. They can do it not only in the school but also from their home. This is possible without any special equipment; the only equipment required is computer with web browser and connection to network. This makes this laboratory interesting not only to the local students, but also to the students from distant areas. The big advantage is that the laboratory has a web camera and a light that gives option to the students from different time zones to work in their daytime. One of my goals was to enable this laboratory in different languages what will also help to spread the range of users able and disposed to use the laboratory to study power quality.

Since the remote laboratory already existed my work was to upgrade it. The laboratory already existed with these practices: a single-phase rectifier, a three-phase rectifier, low energy lamps, the source of a PC and linear loads that creates gap voltage. My work was to improve and extend the antecedent possibilities of the laboratory with the new equipments as variable speed drives, transformer and plug to connect and control the influence of any single phase electric device. On the other hand my work was to improve program in PL7 and the web interface.

For a better understanding of this topic in the next chapter there is an introduction of power quality. Types of the disturbances in the supply network, reasons of them, they effects to the different electrical devices connected to the same network and possible solutions of them.

There are also listed some of the existing remote laboratories which can be found on the Internet, their possibilities and use. After, there is a description of the laboratory, main parts and functions of the main parts. The laboratory at the point from which, it was upgraded. Right after this chapter is that part about changes made on the hardware of the laboratory and also the software of the programmable logic controller (PLC), the program which calculate and show analyze of the disturbances caused by the devices and the interface on the web page.

CHAPTER 3:
POWER QUALITY

3.1. Definition

There are many definitions of the power quality due to the different angles of the view of this topic. The different angle of the view has a utility, to have statistics of very reliable system, other criteria have regulatory agencies and criteria of the manufacturers are usually in this vein.

Since the power quality is ultimately a consumer-driven issue, the definition which take precedence is the manufacturer‘s point of view.

“Any power problem manifested in voltage, current, or frequency deviations that result in failure or miss operation of customer equipment.” [4]

3.2. Price for the low power quality

The first very important publication about this issue have been at the business Week magazine in the 1991, this publication was from EPRI (Electric Power Research Institute) which estimated the annual costs connected with the low power quality in United States to $ 26 milliards.

The next study was in 12 companies with consumption from 5 MVA till 3O MVA. After the 10 months observation the total costs of the low power quality was €600 000. So in conversion it was in average € 50 000 per company.

At one chemical plant, a contactor failed for just less than 6 seconds. Controls and operational equipment were affected, leading to an entire week’s production being halted. The losses included lost production, staff downtime, wasted raw materials, equipment damage and penalties to the electrical network operator. The aggregated cost to the company was just under €7.8 million.

A power surge started a fire in certain elements of the electrical installation causing the plant's cooling system to fail. The resulting overheating damaged capital assets, created significant environmental consequences and the event was declared a "Health & Safety Incident". The cost of this avoidable event was calculated to be €1.4 million, consisting of staff downtime, equipment damage, irrevocably lost revenue, energy supplier penalties, environmental penalties and increased insurance premiums.

A semiconductor manufacturing plant experienced a production line break-down nearly every week. Those breakdowns were caused by dips in the electrical supply voltage. The total cost of each breakdown mounted up quite dramatically, consisting of lost production, raw material losses, staff downtime, the time to recover production loss, equipment damage, and maintenance costs to restart the process. Some of the events also resulted in penalties for unfulfilled client contracts and for environmental issues. In one case, the cost of a single interruption mounted to over €40 million. The total annual cost of the power interruptions in this company's case was estimated to be in the region of €88 million.

3.3. Voltage quality

The most common term for describing the disturbances in the supply network is power quality; however it could be also voltage quality. Technically, in engineering terms, power is the rate of energy delivery and is proportional to the product of the voltage and current. But the power supplier can only control the quality of the voltage, he has no control over the currents that particular loads might draw.

Of course that between the voltage and current is always a close relationship in any practical power system. Although the generator may provide near-perfect sin-wave voltage, the current passing through the impedance of the system can cause a variety of disturbances to the voltage.

However in the technical dictionary is used as the power quality, so in this work will be also considerate as power quality.

3.4. Classes of power quality problems

In the present time there is international afford to standardize definition of power quality terms. Despite of this exist a lot of standards and it is usually difficult to find common characteristics. The most used normalization in European Union is **EN 50160** "Voltage characteristics of electricity supplied by public distribution systems"(or IEEE SCC22) which divide the electromagnetic phenomena into the groups shown in Table 3.1.

Table 3.1. *Comparison of supply voltage requirements according to EN 50160*

No.	Parameter	Supply voltage characteristics according to EN 50160
1	Power frequency	LV, MV: mean value of fundamental measured over 10 s ±1% (49.5 - 50.5 Hz) for 99.5% of week -6%/+4% (47- 52 Hz) for 100% of week
2	Voltage magnitude variations	LV, MV: ±10% for 95% of week, Mean 10 minutes rms values
3	Rapid voltage changes	LV: 5% normal 10% infrequently Plt ≤ 1 for 95% of week MV: 4% normal 6% infrequently Plt ≤ 1 for 95% of week
4	Supply voltage dips	Majority: duration <1s, depth <60%. Locally limited dips caused by load switching on: LV: 10 - 50%, MV: 10 - 15%
5	Short interruptions of supply voltage	LV, MV: (up to 3 minutes) few tens - few hundreds/year Duration 70% of them < 1 s
6	Long interruptions of supply voltage	LV, MV: (longer than 3 minutes) <10 - 50/year
7	Temporary, power frequency overvoltages	LV: <1.5 kV rms MV: 1.7 Uc (solid or impedance earth) 2.0 Uc (unearthed or resonant earth)
8	Transient overvoltages	LV: generally < 6kV, occasionally higher; rise time: ms - μs. MV: not defined
9	Supply voltage unbalance	LV, MV: up to 2% for 95% of week, mean 10 minutes rms values, up to 3% in some locations
10	Harmonic voltage	LV,MV see below
11	Interharmonic voltage	LV, MV: under consideration
12	fluctuations of voltage magnitude (flicker)	LV,MV: 95% of week

3.4.1 Transients

Transients can be classified into two categories, impulsive and oscillatory, which are discussed in the following subsections.

3.4.2 Impulsive transients

An impulsive transient is a sudden non power frequency change in the steady-state condition of voltage or current, or both, which is unidirectional in polarity either positive (swell) or negative (sag). Impulsive transients are normally characterized by their rise and decay times. They can also be described by their spectral content. For example the swell, a 1.2-/50-ms 4000-V impulsive transient rises to its peak value of 4000 V in 1.2 ms, and then decays to half its peak value in 50 ms. The most common cause of impulsive transients is lightning.

3.4.3 Oscillatory transients

An oscillatory transient consists of a voltage or current whose instantaneous value changes polarity rapidly. It is described by its spectral content. Table 3.2 gives some examples of oscillatory transients. Figure 3.1 shows oscillatory transient of low frequency caused by capacitor bank energetization.

***TABLE 3.2.** Oscillatory transients, according to IEEE SCC22*

	Typical Spectral Content	Typical Duration	Typical Voltage Magnitude	Examples
Low frequency	300–900 Hz	0.5–10 ms depending upon system damping	1.3–1.5 pu can reach 2.0 pu	Capacitor bank energization
Medium frequency	Tens of kHz	20 μs	0–8 pu	1. Back-to-back capacitor energization 2. Cable switching 3. System response to an impulsive transient
High frequency	>500 kHz	5 μs	0–4 pu 0.1 pu (less the 60-Hz component)	1. Switching transients 2. Commutation transients in power electronic devices

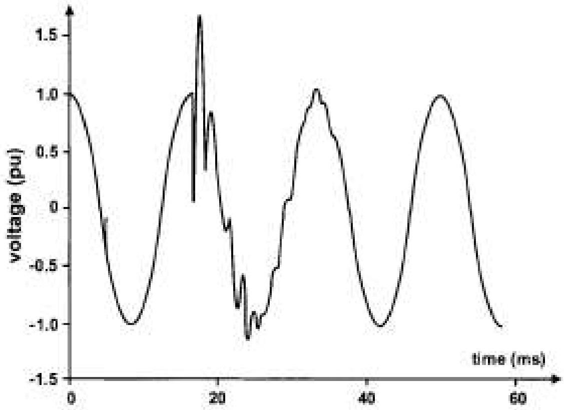


Figure 3.1. *Oscillatory transients*

3.4.4 Voltage sags (dips)

Voltage sags (in America) are referred to as voltage dips (in Europe). Voltage sags are defined as a reduction in voltage for a short time. The duration of voltage sag is less than 1 minute but more than 10 milliseconds (0.5 cycles). The magnitude of the reduction is between 10 percent and 90 percent of the normal root mean square (rms) voltage at 50 Hz. The average of the squares of all the instantaneous values of a cycle and is equal to 0.707 ($1/\sqrt{2}$) times the peak value of the sine wave. Other voltage reduction disturbances often occur intermittently, while voltage sags occur once, for a short time, as shown in Figure 3.2.

Utilities and end users can cause voltage sags on transmission and distribution systems. For example, a transformer failure can be the initiating event that causes a fault on the utility power system that result in voltage sag. These faults draw energy from the power system. Voltage sag occurs while the fault is on the utility's power system. As soon as a breaker clears the fault, the voltage returns to normal. Transmission faults cause voltage sags that last about 5 cycles, or 0.10 second. Distribution faults last longer than transmission faults, while large motor loads can cause voltage sag on utility's and end user's power systems. Compared to other power quality problems affecting industrial and commercial end users, voltage sags occur most frequently. They reduce the energy being delivered to the end user and cause computers to fail, adjustable-speed drives to shut down, and motors to stall and overheat. Solutions to voltage sag problems include equipment that protects loads that are sensitive to voltage sags. Examples of these types of equipment include ferroresonnant, i.e., constant voltage transformers; dynamic voltage restorers; superconducting energy storage devices; flywheels; written pole motor-generator sets; and uninterruptible power supplies (UPS).

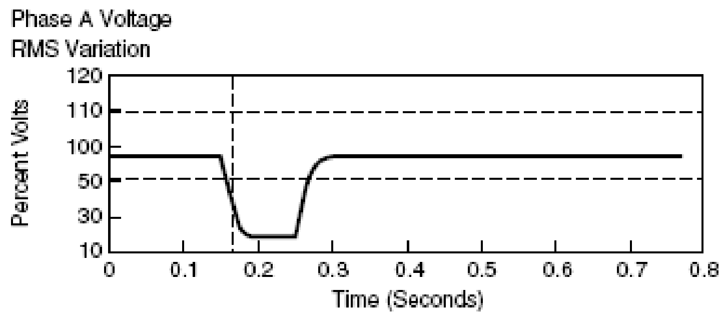


Figure 3.2. *Voltage sag plot.*

3.4.5. Voltage swells

Voltage swells, or momentary overvoltage, are rms voltage variations that exceed 110 percent of the nominal voltage and last for less than 1 minute. Voltage swells occur less frequently than voltage sags. Single line to ground faults cause voltage swells. Examples of single-line to ground faults include lightning or a tree striking a live conductor. The increased energy from a voltage swell often overheats equipment and reduces its life. Figure 3.3. illustrates a typical voltage swell caused by a single-line to ground fault occurring in an adjacent phase.

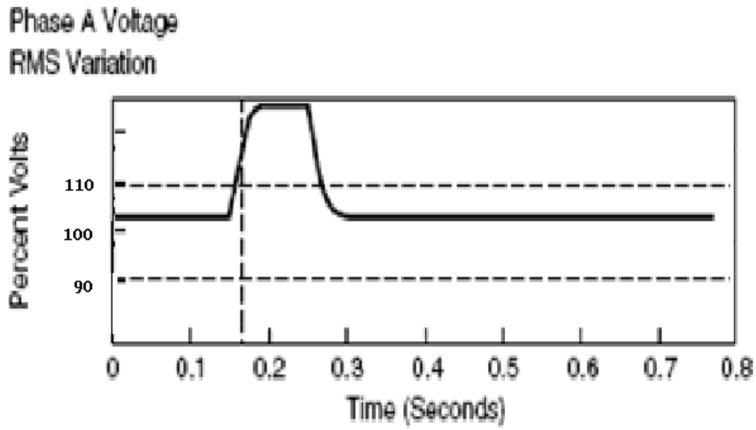


Figure 3.3. *Voltage swell plot.*

3.4.6 Undervoltages

Undervoltages occur when the voltage drops below 90 percent of the nominal voltage for more than 1 minute. They are sometimes referred to as "brownouts," although this is an imprecise not technical term that should be avoided. They are recognized by end users when their lights dim and their motors slow down. Too much load on the utility's system, during very cold or hot weather, for example, or the loss of a major transmission line serving a region can cause undervoltages. Overloading inside an end user's own distribution system can cause undervoltages. Sometimes utilities deliberately cause undervoltages to reduce the load during heavy load conditions. Reducing the voltage reduces the overall load, since load is voltage times current. Undervoltages can cause sensitive computer equipment to read data incorrectly and motors to stall and operate inefficiently. Utilities can prevent undervoltages by building more generation and transmission lines. Figure 3.4 shows a typical plot of undervoltage versus time.

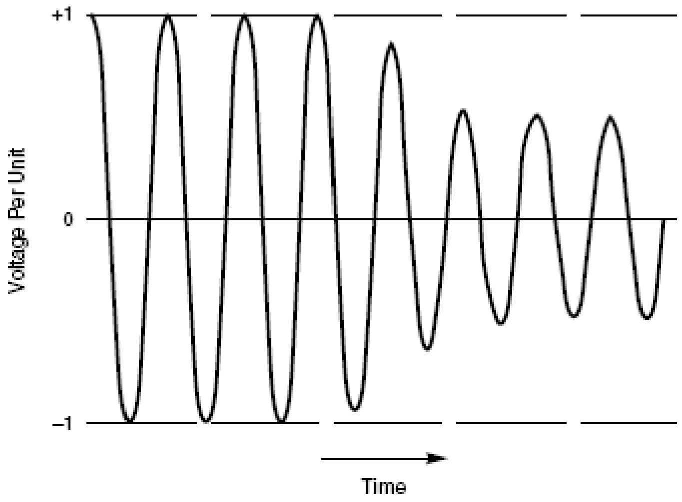


Figure 3.4. *Undervoltage plot. (Courtesy of IEEE, Std. 1159-1995, Copyright © 1995. All rights reserved.)*

3.4.7 Long-duration overvoltages

Long-duration overvoltages are close cousins to voltage swells, except they last longer. Like voltage swells, they are rms voltage variations that exceed 110 percent of the nominal voltage. Unlike swells, they last longer than a minute.

Several types of initiating events cause overvoltages. The major cause of overvoltages is capacitor switching. This is because a capacitor is a charging device. When a capacitor is switched on, it adds voltage to the utility's system. Another cause of overvoltage is the dropping of load. Light load conditions in the evening also cause overvoltages on high voltage systems. Another common cause of overvoltage is the misstating of voltage taps on transformers. Extended overvoltages shorten the life of lighting filaments and motors. Solutions to overvoltages include using inductors during light load conditions and correctly setting transformer taps. Figure 3.5. shows a typical plot of overvoltage versus time.

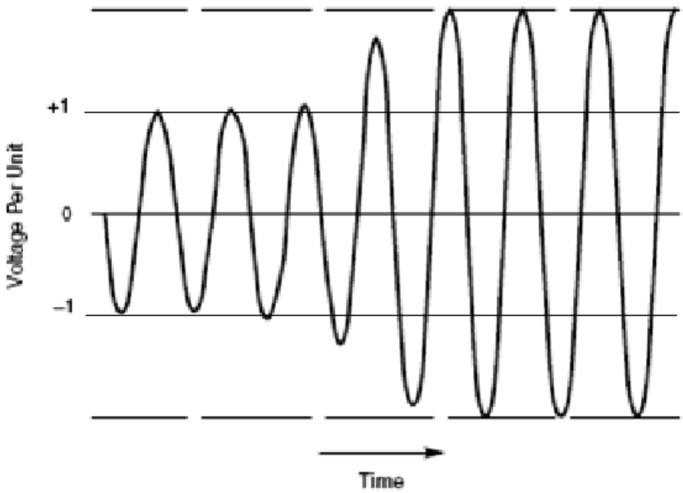


Figure 3.5. *Overvoltage plot. (Courtesy of IEEE, Std. 1159-1995, Copyright © 1995. All rights reserved.)*

3.4.8. Sustained Interruption

Sustained (or long) interruption is the most severe and the oldest power quality event at which voltage drops to zero and does not return automatically. EN 50160 subdivides voltage interruptions into: Short supply interruptions (duration less or equal to 3 min) and Long supply interruptions (duration > 3 min). The number and duration of long interruptions are very important characteristics in measuring the ability of a power system to deliver service to customers. The most important causes of sustained interruptions are: fault occurrence in a part of power systems with no redundancy or with the redundant part out of operation, an incorrect intervention of a protective relay leading to a component outage and scheduled (or planned) interruption in a low voltage network with no redundancy.

3.4.9. Voltage unbalance

A three-phase power system is called balanced or symmetrical if the three-phase voltages and currents have the same amplitude and are phase shifted by 120° with respect to each other. If either or both of these conditions are not met, the system is called unbalanced or asymmetrical. It can be calculated by the formula:

Voltage unbalance= 100 x MD / AV (1)

Where MD=maximum deviation of average voltage

AV= average voltage (sum of voltage of each phase)/3.

In most practical cases, the asymmetry of the loads is the main cause of unbalance. At high and medium voltage level, the loads are usually three-phase and balanced, although large single- or dual-phase loads can be connected, such as AC rail traction (e.g. high-speed railways) or induction furnaces.

Low voltage loads are usually single-phase, e.g. PCs or lighting systems, and the balance between phases is therefore difficult to guarantee. In the layout of an electrical wiring system feeding these loads, the load circuits are distributed amongst the three-phase systems, for instance one phase per floor of an apartment or office building or alternating connections in rows of houses. Still, the balance of the equivalent load at the central transformer fluctuates because of the statistical spread of the duty cycles of the different individual loads. Abnormal system conditions also cause phase unbalance. Phase-to-ground, phase-to-phase and open-conductor faults are typical examples. These faults cause voltage dips in one or more of the phases involved and may even indirectly cause overvoltages on the other phases.

Most equipment, especially motors, can tolerate a voltage unbalance of 2 percent. A voltage unbalance greater than 2 percent will cause motors and transformers to overheat. This is because a current unbalance in an induction device, like a motor or transformer, varies as the cube of the voltage unbalance applied to the terminals. Potential causes of voltage unbalance include capacitor banks not operating properly, single phasing of equipment, and connecting more single-phase loads on one phase than another.

3.4.10. DC Offset

The presence of a dc voltage or current in an ac power system is termed DC Offset. This phenomenon can occur from the effect of half-wave rectification or as the result of a geomagnetic disturbance. Half-wave rectification is sometimes used in light dimmer circuits and TV power supplies. Direct current in alternating current networks can cause: transformer saturation with consequent increased losses, additional heating, and reduction in transformer life, and the electrolytic erosion of grounding electrodes.

3.4.11. Current harmonics

Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment has caused harmonics to become more common. An analysis of the sine wave architecture provides an understanding of the basic anatomy of harmonics. Harmonics are integral multiples of the fundamental frequency of the sine wave. They add to the fundamental 50Hz waveform and distort it. They can be 2, 3, 4, 5, 6, 7, etc., times the fundamental. For example, the third harmonic is 50 Hz times 3, or 150 Hz, and the sixth harmonic is 50 Hz times 6, or 300 Hz.

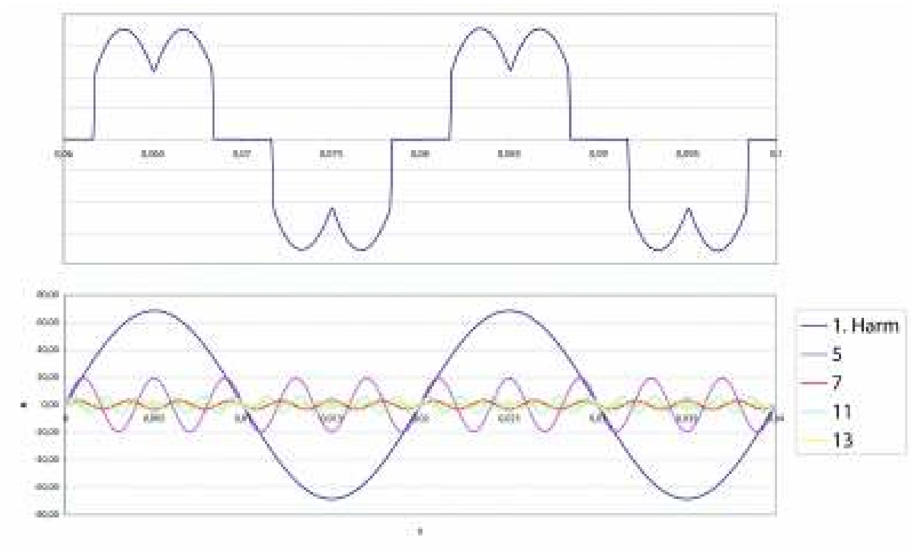


Figure 3.6. *Composite harmonic distortion*

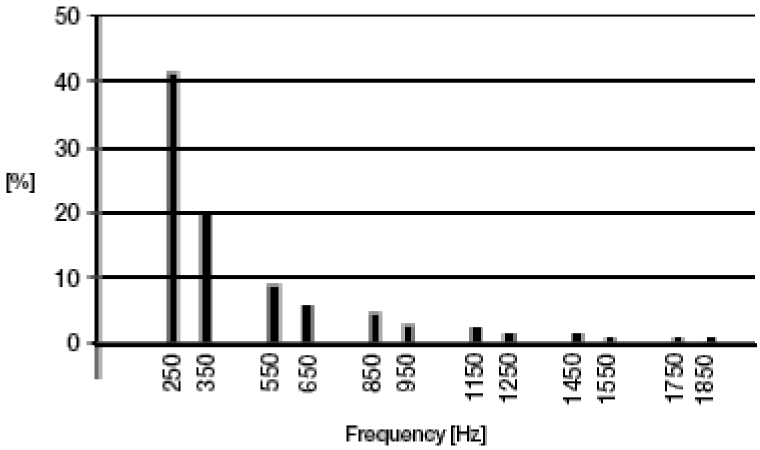


Figure 3.7. *Graph of harmonic distortion*

They are usually caused by nonlinear loads, like adjustable speed drives, solid-state heating controls, electronic ballasts for fluorescent lighting, switched-mode power supplies in computers, static UPS systems, electronic and medical test equipment, rectifiers, filters, and electronic office machines. Nonlinear loads cause harmonic currents to change from a sinusoidal current to a no sinusoidal current by drawing short bursts of current each cycle or interrupting the current during a cycle. This causes the sinusoidal current waveform to become distorted. The total distorted wave shape is cumulative. The resulting no sinusoidal wave shape will be a combination of the fundamental 50-Hz sine wave and the various harmonics.

The harmonic currents generated by the load – or more accurately converted by the load from fundamental to harmonic current – have to flow around the circuit via the source impedance and all other parallel paths. As a result, harmonic voltages appear across the supply impedance and are present throughout the installation.

It is very important that both voltage and current values are measured and that quoted values are explicitly specified as voltage and current values. Conventionally, current distortion measurements are suffixed with 'I', e.g. 35 % THDI, and voltage distortion figures with 'V', e.g. 4 % THDV

3.4.12. Voltage harmonics

Harmonic currents and voltages have a detrimental effect on utility and end-user equipment. They cause overheating of transformers, power cables, and motors; inadvertent tripping of relays; and incorrect measurement of voltage and current by meters. Harmonic voltages cause increased iron losses in transformers. Harmonics cause motors to experience rotor heating and pulsating or reduced torque. Not only can harmonics cause power quality problems on the end user or the utility serving the end user, but they can cause problems on other end users. For example, a third harmonic generated by a transformer was injected into a utility's system and transmitted to a city miles away and caused the digital clocks to show the wrong time. The extent of harmonic's harmful effects is related to the ratio of harmonic current or voltage to the fundamental current or voltage. The maximum overvoltage for transformers is 5 percent at rated load and 10 percent at no load. Electronic equipment cannot tolerate more than a 5 percent harmonic voltage distortion factor, with the single harmonic being no more than 3 percent of the fundamental voltage. Higher levels of harmonics result in erratic malfunction of the electronic equipment. Harmonics can cause relays and meters to malfunction.

3.4.13. Interharmonics

Interharmonics are defined as frequency components of voltages or currents that are not an integer multiple of the normal system frequency (e.g., 50 or 60 Hz). The main sources of interharmonics are static frequency converters, cycloconverters, induction motors, and arcing devices. Power line carrier signals can be considered as interharmonics. The effects of interharmonics are not well known but have been shown to affect power line carrier signaling and induce visual flicker in display devices such as cathode ray tubes (CRTs).

3.4.14. Notching

Three-phase converters that convert ac to dc require commutation of the alternating current from one phase to another. During this period, there is a momentary short circuit between the two phases. This causes a periodic voltage disturbance, which is called notching. The frequency components associated with notching can be quite high and may not be characterized with the help of measurement equipment normally used for harmonic analysis.

Notching can be characterized witch the following properties:

- Notch depth: average depth of the line voltage notch from the sinusoidal waveform at the fundamental frequency;

- Notch width: the duration of the commutation process;
- Notch area: the product of notch depth and width;
- Notch position: where the notch occurs on the sinusoidal waveform.

Some standards set limits for notch depth and duration (with respect to the system impedance and load current) in terms of the notch depth, the total harmonic distortion THDv of supply voltage, and the notch area for different supply systems.

The severity of the notch at any point in the system is determined by the source impedance and isolating inductance between the converter and the point being monitored.

3.4.15. Noise

Noise refers to unwanted electrical signals (with broadband spectral content lower than 200 kHz) that produce undesirable effects in the circuits of control systems in which they occur. Noise in power systems can be caused by power electronic devices, control circuits, arcing equipment, loads with solid-state rectifiers, and switching power supplies. Noise problems are often exacerbated by improper grounding. There are two types of noise voltages: Common-mode noise voltage: A noise voltage that appears between current carrying conductors and ground. That is, this noise voltage appears equally and in phase from each current-carrying conductor to the ground. Normal-mode noise voltage: A noise voltage that appears between or among active circuit conductors, but not between the grounding conductor and the active circuit conductors. Noise disturbs electronic devices such as microcomputer and programmable controllers. The problem can be mitigated by using filters, isolation transformers, and some line conditioners.

3.4.16. Voltage fluctuations (flicker)

Voltage fluctuations are rapid changes in voltage within the allowable limits of voltage magnitude of 0.95 to 1.05 of nominal voltage. Devices like electric arc furnaces and welders that have continuous, rapid changes in load current cause voltage fluctuations. Voltage fluctuations can cause incandescent and fluorescent lights to blink rapidly. This blinking of lights is often referred to as "flicker." This change in light intensity occurs at frequencies of 6 to 8 Hz and is visible to the human eye. It can cause people to have headaches and become stressed and irritable. It can also cause sensitive equipment to malfunction. The solution to voltage fluctuations is a change in the frequency of the fluctuation. In the case of an arc furnace, this usually involves the use of costly but effective static VAR controllers (SVCs) that control the voltage fluctuation frequency by controlling the amount of reactive power being supplied to the arc furnace.

3.4.17. Power frequency variations

At any instant, the frequency depends on the balance between the load and the capacity of the available generation. When dynamic balance changes, small changes in frequency occur. In modern interconnected power systems, frequency is controlled within a tight range as a result of good governor action. Frequency variations beyond ±0.1 Hz are likely to occur under fault conditions or from the loss of a major load or generating unit. However, in isolated systems, governor response to abrupt load changes may not be adequate to regulate them within the narrow bandwidth required by frequency-sensitive equipment. Voltage notching can sometimes cause frequency or timing errors on power electronic machines that count zero crossings to derive frequency or time. The voltage notch may produce additional zero crossings that can cause frequency or timing errors and affect the performance of digital electric clocks.

CHAPTER 4: REMOTE LABORATORIES

4.1. Introduction to the remote laboratories.

A remote laboratory is defined as a computer-controlled laboratory, which can be accessed and controlled externally through some communication medium, for example, trough the Internet. A laboratory has some special equipment to which we can not enter personally. The concept of a web-based laboratory is not new. Remote laboratories are essential to e-learning platforms in scientific and technical disciplines. Nowadays with the spread of the Internet connection to the majority of the houses, offices, and to the many public places, the possibility to control project which are operating at the moment is big advance. They were not designed to be the replacement of the ordinal methods of the education but as the complementary form of the education.

Remote laboratories are interesting, and often the only option how to give an opportunity to the students to do special experiments with the equipment which is too special or too expensive to provide to all of the students in the class. For the one remote laboratory is necessary just one of this equipment.

On the other hand, the price of the laboratory is increasing due to necessity of the special equipment to be more autonomous, equipment to connect, to receive the orders and send the results through the Internet. But also due to necessary of unique software to control the processes held in the laboratory, software which provides interaction between user and the equipment, to transfer the orders to the language understandable to the laboratory and outputs suitable to understand to the user and necessary of maintenance of the laboratory. Another elevation of the costs is the price of electricity consumed by all the equipment and price of the internet connection paid to the provider.

4.2. A typology of Internet accessible labs

4.2.1. Real-Virtual labs

Types of remote laboratories are basically divided according to real or virtual model. Real model is based on getting information from real models, visualization, providing information in the form of numbers and graphs. Second one is based on the same features but models are only virtual and realized on the base of calculations, which help us to make calculations easier and make calculated results more accessible. They use simultaneously the help of own algorithms in programs or laboratory applications, for example: Mathworks Matlab server, Simulink, National Instruments Labview.

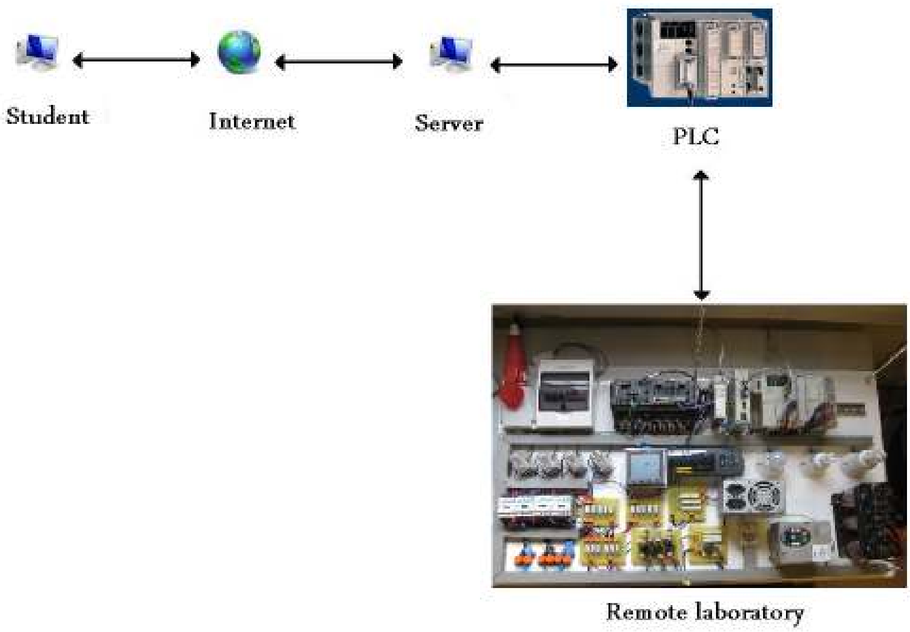


Figure 4.1. Schematic of real remote laboratory

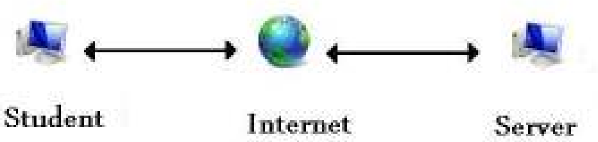


Figure 4.2. Schematic of virtual remote laboratory

4.2.2. Architecture

In the MIT they decided that a single shared architecture is too limiting. They distinguished three types of laboratory experiments.

The Batched Experiment: In a batched experiment, the student specifies all parameters that govern the execution of the experiment before the experiment starts. The lab session consists of submitting an experiment protocol, executing the experiment, and then retrieving and analyzing the results. Typically, batched experiments run quickly so that scheduling is rarely necessary.

The Sensor Experiment: In a sensor experiment, the student usually can not specify any parameters although he may be able to select the particular sensor data that he wishes to receive. Running the experiment consists of subscribing to real time sensor data, usually presented in a graphical user interface such as a virtual strip chart. The system may provide options to filter the data or to transform it as well as to access archival data. Long running sensor subscriptions may benefit from implementing trigger or alarm mechanisms. Imagine an online seismometer that notifies a student of a seismic event through email or instant messaging. The detection of a seismic event that passed a specified threshold might trigger more frequent sampling or complementary data presentations.

Sensor experiments frequently have very asymmetric data flows. It takes few bits to subscribe to a sensor, but the resulting data stream from the sensor to the student's client may require a great deal of bandwidth. Some sensors may only provide best efforts to deliver continuous data with no guarantee that all samples will arrive. Other systems may provide archival quality data but perhaps with a variable lag time.

The Interactive Experiment: In an interactive experiment, the student typically sets a series of parameters, initiates the experiment, and then monitors the experiment's course, changing control parameters as necessary. Conceptually, an interactive experiment can be thought of as a sequence of alternating control and monitoring intervals. In general, the control intervals have many of the characteristics of a batched experiment, and the monitoring intervals resemble sensor experiments. The record of an experiment session typically includes both time-stamped control and sensor data as well as other forms of documentation that may include images or video. This is also case of our remote laboratory.

4.3. Remote laboratories on the Internet

As have been mentioned there are two types of the remote laboratories, virtual based and real based. Here will be described just real based because they work on very different base.

The University of Tennessee at Chattanooga: Physical laboratory

Figure 4.3. 5 HP, 3-phase motor on the left, coupling, DC Generator on the right

This laboratory is running on the Internet since June, 1995. Despite of that this laboratory is 15years old it have some interesting projects. It has four main experiments: Voltage, Speed, Pressure of the air and Flow of the liquid. It have possibility to choose the optimal input function from: Constant, Step, Sinusoidal, Pulse, Custom, Ramp, Relay and also have different settings available like amplitude, frequency, length of experiment and others. It is available in four languages in English, Spanish, German and France.

Technical University of Bergakademie Freiberg: Robot football

The goal of this recent robotics project is to allow the user to control soccer playing robots via intuitive interfaces such as the Nintendo Wii stick or websites. On the website interface is possible in specified days and hours control one of the robots or just look on the play as spectator.

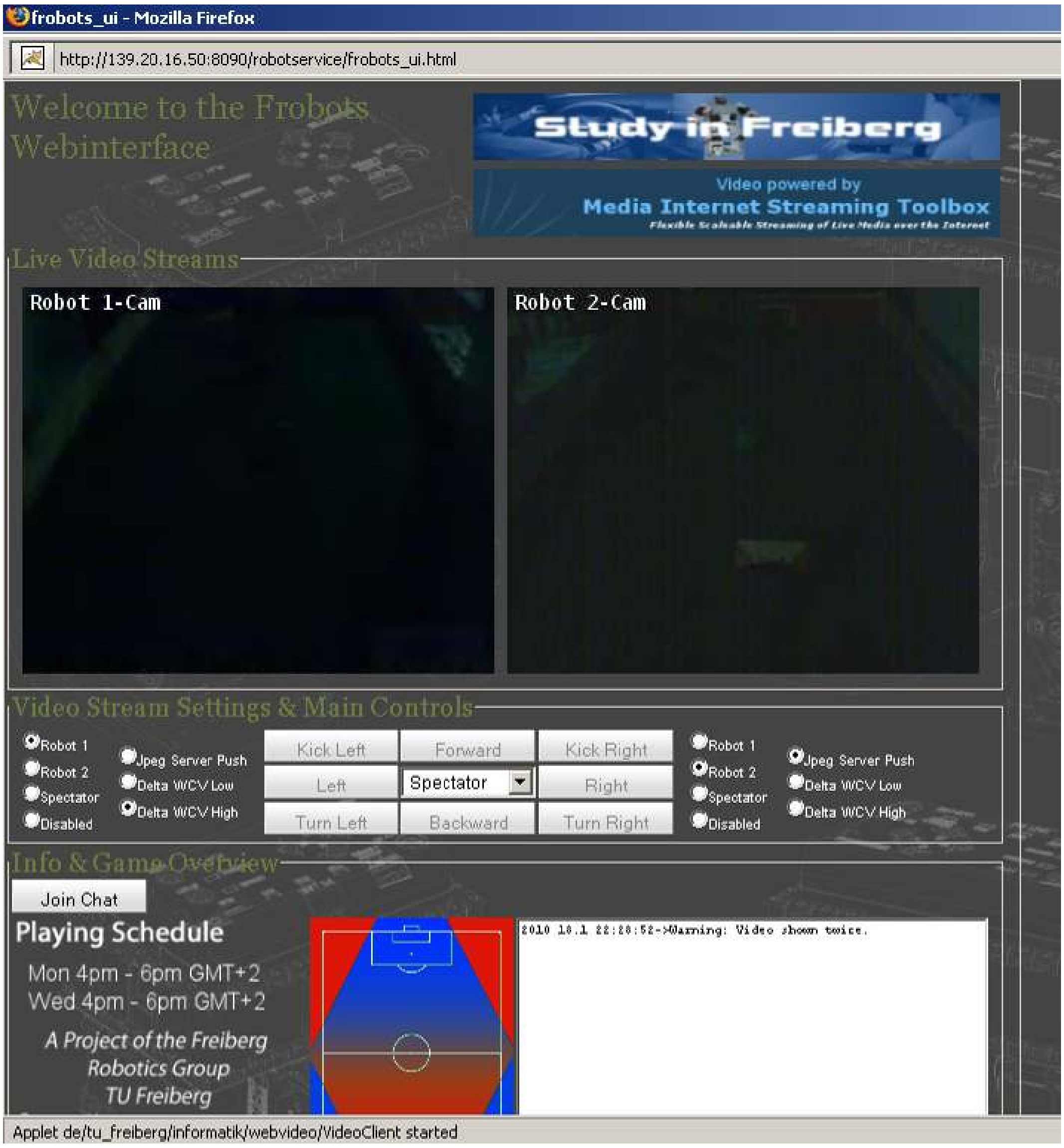


Figure 4.4. Controlling of the robots

Massachusetts Institute of Technology: Technical labs

iLab teams have created remote laboratories at MIT in microelectronics, chemical engineering, polymer crystallization, structural engineering, and signal processing as case studies for understanding the complex requirements of operating remote lab experiments and scaling their use to large groups of students at MIT and around the world.

Figure 4.5. Microelectronic lab

Network for Earthquake Engineering Simulation Cyberinfrastructure Center (NEESit): Earthquake simulation

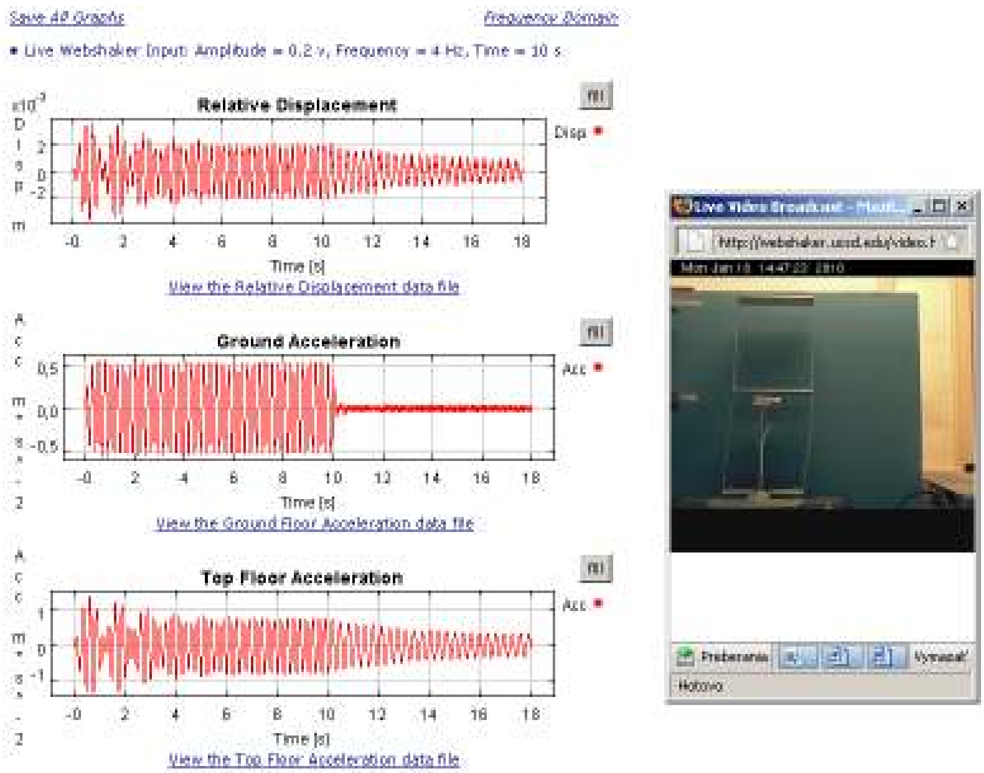


Figure 4.6. Left side show charts of results.

Right side show video from the laboratory

The UC San Diego Webshaker is a live earthquake experiment conducted over the Internet. With a live video broadcast and precise measurements from sensors located on the test structure. It is possible to design the earthquake base motion by specifying the frequency, amplitude, and test duration.

The command to shake is received by the web server at UCSD, which processes the command and then runs the shaker computer program accordingly. This program constructs the control signal, which is routed to the power amplifier that drives the electro-magnetic shake table. The shake table delivers base motion to the test structure in the same way that an earthquake shakes buildings and other structures.

While the shaker and test structure are responding to the command signal, the server is also collecting data from sensors located on the structure by repeatedly converting the analog electrical signals from each sensor into discrete numbers. Once the test is complete, the data is sent to user's computer and presented in several x-y graphs, displaying the response from different parts of the structure. Currently they have only one storage of aluminium structure with two LVDT's attached to the structure, measuring the displacement of each floor of the structure during the experiment.

University of South Australia: Frequency laboratory

Figure 4.7. Graphical user interface

This laboratory is used by academic staff for teaching and demonstrations during lectures, and by students for conducting their experiments remotely on real laboratory equipment. The application presents users with graphical user interfaces that look like actual laboratory instruments. They click the buttons and turn the knobs with their mouse, interacting with it as they would with the real device. What makes NetLab unique is that when students interact with the GUIs, they are actually operating real instruments that are set up in a laboratory in some remote location, controlling them via the internet. The output they see on the instrument's display panels is not a simulation, but is actual data being read from the real instruments, in real time. This is totally different attitude to this topic as the next laboratory

Blekinge Institute of Technology, Ronneby Sweden: Electrical lab

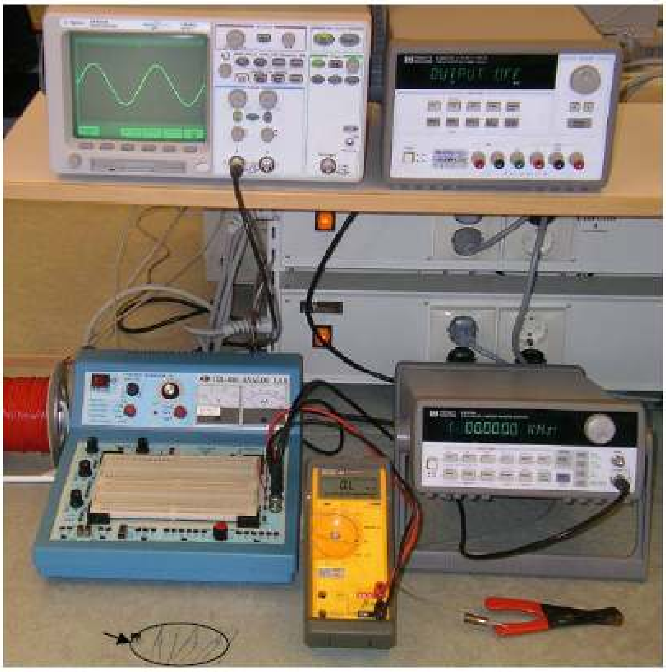
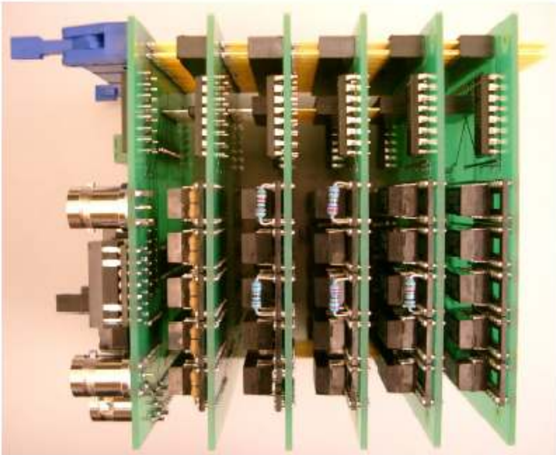


Figure 4.8. *Classical lab*

Figure 4.9. *Remote lab*



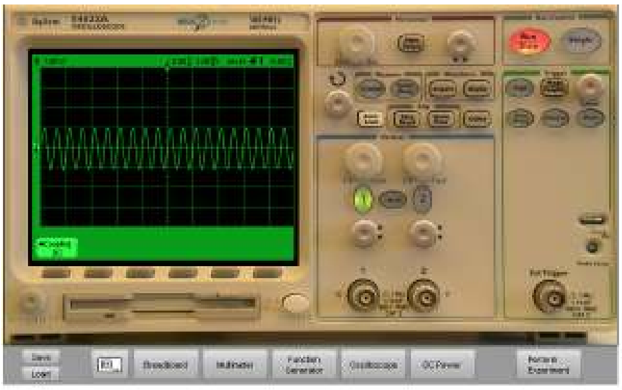


Figure 4.10. *Installed components* ***Figure 4.11.*** *Results of the measuring*

Probably the best remote laboratory which can be found on the Internet. This laboratory is complete substitution for the classical laboratory. The new remote laboratory for hardware experiments emulates a local lab and was launched, on 10 March 2004. It is designed to support traditional lab sessions in electricity and electronics. Simulator experience is no longer required, because this laboratory is using the switch board with installed components (the components are in sockets, so they can be replaced). Figure of the board is shown above.

The experiment starts with positing the virtual electrical components on the virtual solderless board in the web site. Than it continues with change of the settings of the different devices in web site. They are simulated very well so working with them is just like working with the real equipment. After pressing the button to start measuring, the circuit is checked by the software if is everything connected correctly and if is the switch board connect the components in the right order (in less than in 0,1s), the values are scanned and circuit is disassembled immediately. This is very important, because, after less then one second the equipment is again ready for the next measurement from another user.

This laboratory really offers the face-to-face interaction without any simulation, all the measurements are really held. Also the possibilities of connecting of the components are really wide, and give to the student opportunity to assembly their own circuits.

CHAPTER 5: COMPONENTS OF REMOTE POWER QUALITY LABORATORY

This remote lab of the power quality can be divided into this different parts: power supply of the practices, the automation platform, the 24 V power supply, network card, contactors, the testing equipment, current transformers, measuring equipment and webcam.

5.1. Power supply

The monitoring system is supplied from a fuse box located in the Aula Schneider that provides three-phase voltage 400V.

Figure 5.1. *Main power supply*

It has a 3 phases plug with 5-wires (3 phases + neutral + earth) from there the cable continue to the fuse box. The output voltage is protected here with two fuses magnetotermics (one three-phase and another one-phase).

Figure 5.2. *Fuse box*

5.2. Automation platform, the 24 V power supply and network card,

The head apparatus in the remote laboratory is an automation platform. For this application, is used PLC TSX Micro 3722 v6.0 by Telemecanique, Schneider-Electric. This automaton has inserted an input and output card TSX DMZ 28DR I/O and TSX DSZ 32T2 I/O. To establish communication between the laboratory and the Internet, is used a network card Factory Cast TSX ETZ 410. This equipment has a default website, which can be accessed through any web browser. Because of this, the tests shall be steered through this website.

It is programmed through software PL7-PRO, this automat drives the laboratory, decide at each moment which part of the lab is activated (by Factory Cast). To supply the power circuits, four contactors and twelve relays are used. The first of contractors is the main contactor, supplying all of the equips. The rest of contactors are used to enable or disable each time each of the tests.

The supply comes via a 24V power supply ABL7 RE2403.

Figure 5.3. *Power supply, TSX ETZ 410, TSX Micro 3722*

5.3. Contactors

The assembly consists of four contactors. There is one contactor governing all the practices. Than there are three contactors, each for one practice. Each of these contactors is able to open or close the input voltage of the practices. Figure 5.4. shows the model used in the laboratory contactor.

Figure 5.4. *Contactors*

Also there are relays to connect or disconnect the outputs. They are used with the practices where is current below 1,25A.

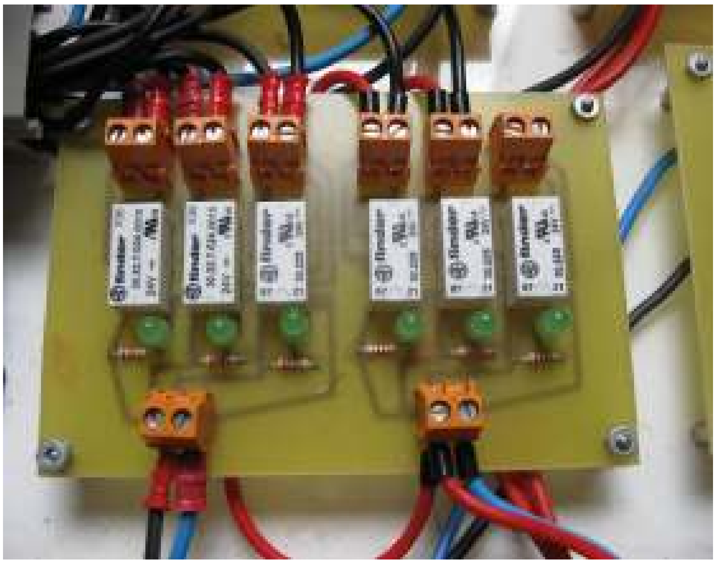


Figure 5.5. *Relays*

As already mentioned, the contactors and relays are programmed that may not be activated more than one practice at a time.

As can be seen on figures each practice also has own LED to indicate which one is working

5.4. Measuring transformers

The current transformers are used only because the equips measure just values five times higher than those obtained. To make this happen, they are wired so that the display intensity increased. In the next figure, we can observe how are mounted transformers in the remote laboratory. We can see that each phase and neutral is caught in a transformer.

Figure 5.6. *Current transformers*

5.5. Measuring equipment

Measuring equipments are responsible for monitoring the values measured and inform about power quality. We found two different monitoring teams. The first is the Circuit Monitor 4000. This network analyzer has great advantages in monitoring of different variables. Also has a screen through which you can access the menu CM4000, and integrated Ethernet ECC21 card, with which, through the network we can see in the real time the quantities measured at the time.

Figure 5.7. *CM4000 with card ECC21 and display*

The other equipment, the Power Meter 800, is simpler measurer. We may also view the measures taken over Ethernet, through RS485 communication by the Circuit Monitor 4000.

Figure 5.8. *PM8000*

5.6. Web-cam

With the insertion of a webcam in the laboratory, the user can watch at all times the structure and development laboratory, practices which are held, through the Internet. By the webcam may view that practices started because each one is equipped with a LED which is turned on or off according to whether it is his practice which is working or not.

Figure 5.9. *Web-cam*

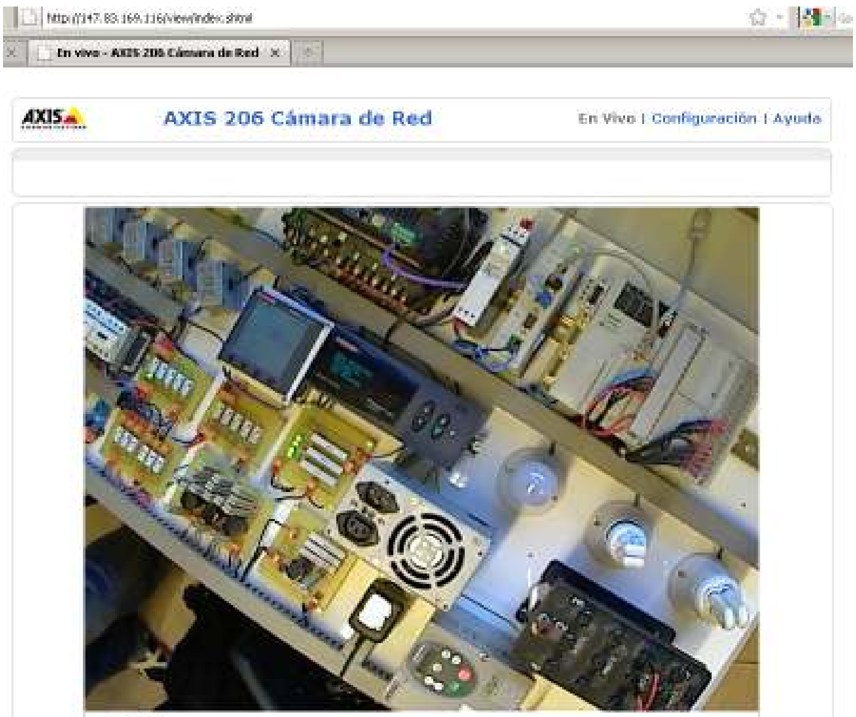


Figure 5.10. *Web-cam in action*

5.7. Illumination

For a complete remote laboratory, which may be used at any time of day and from anywhere in the world, the lab needed some kind of enlightenment that could be selected, like the rest of laboratory practices, through the keypad of the website, and at the time, not introduced into any network might mate with harmonic the rest of views made through the network analyzer circuit monitor 4000. The choice was simple, use an incandescent light bulb commanded by a new output of the PLC and operated through a relay with a corresponding LED activated relay, same setup as for low-power lamps.

Figure 5.11. *Bulb*

Here is the signal that causes the bulb on the net, and we see that is a pure sine wave does not have any interference.

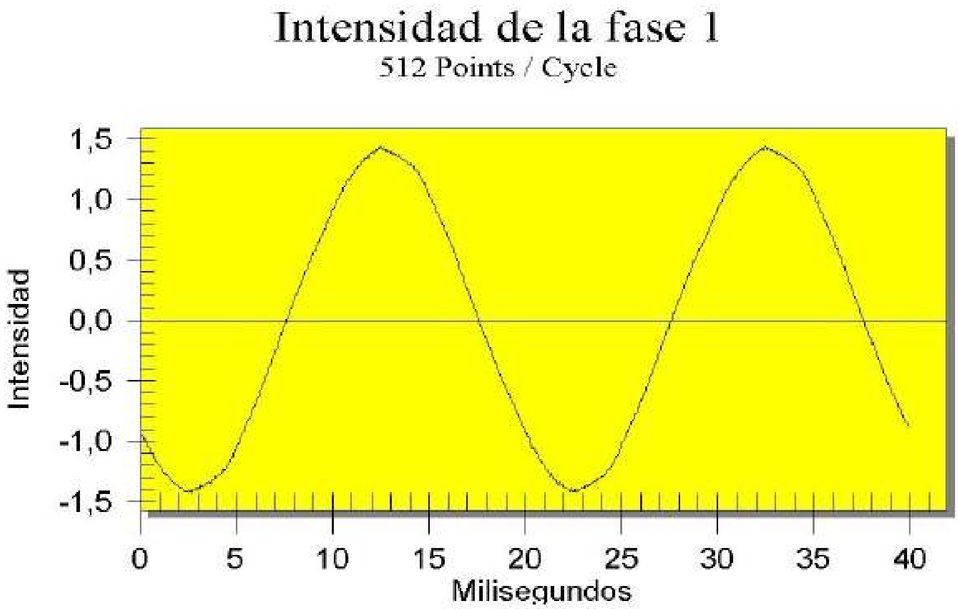


Figure 5.12. *Current of the bulb*

CHEAPTER 6:
DISTURBANCE PLANTS

In the remote laboratory are right now available seven practices which are fully functionally and we can examine them through web browser.

Currently there are eight remote laboratory practices. First five have been there before:

- Linear load
- Single Phase Bridge Rectifier
- Three-Phase Bridge Rectifier
- Energy-saving lights
- PC Source

Last three practices have been added by me:

- Variable speed drives
- Electrical plug
- Transformer

6.1. Linear load

By this practice, we can visualize the effect of voltage dips.

The diagram in Figure 6.1. corresponds to the circuit of this practice. This circuit consists of two switches. These switches are connected directly to the terminals 22, 23 and 25 of the module input / output TSX DMZ 28DR. The terminals 22 and 23 correspond directly to the outputs Q6.1 and Q6.2 of PLC. In this way, through the keypad on the Web page, you can turn ¾ of the load by activating Q6.1, as it was 20 kΩ with two switches opened, it will be 15 kΩ with a one switch opened and one closed. This will get the first dip of the tension. For finer voltage dip, the load is reduced to 10kΩ (half of the first load), this is achieved by activating the output Q6.2. and so closing the other switch. As you can see in the scheme in terminals of one of resistors have a voltmeter. This would correspond to the voltage taken across this resistance with the recording equipment Power Meter as 800. Along with each series resistor has a diode and an LED connected in parallel with one diode and another LED on the contrary, the reason of the diodes is to see through the webcam or the place that resistance on at the moment. The why of diodes in series with each LED is simple protection for LED's.

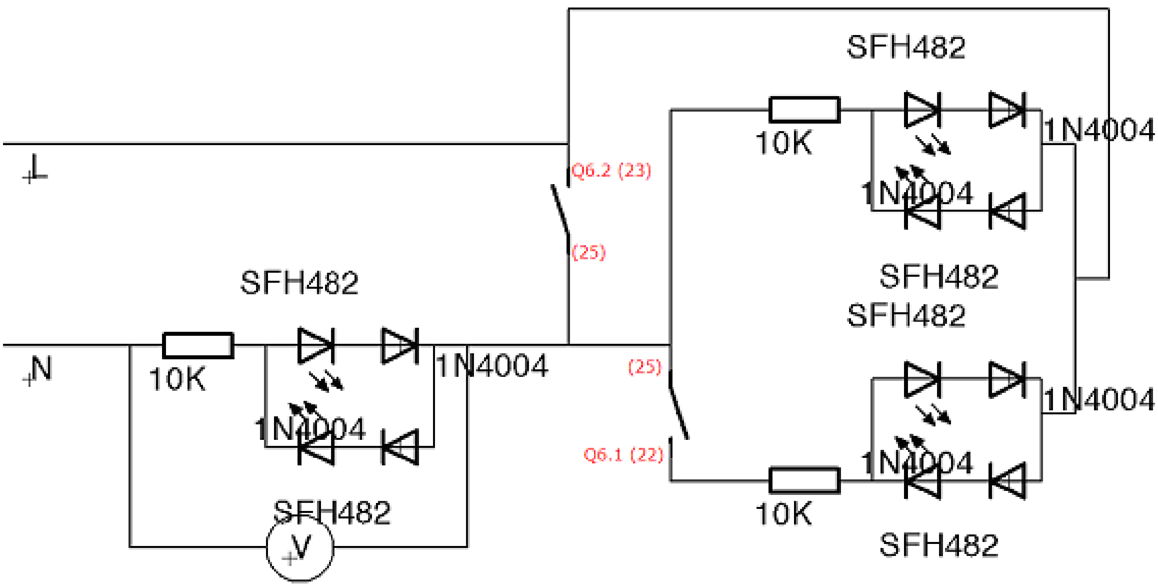


Figure 6.1. *Circuit diagram of linear load practice.*

Components:

- Three ceramic resistors 10 W 10 kΩ.
- Six diodes.
- Six green LED's

Calculations

As previously stated, the circuit consists of three resistors of 10 kΩ. Was not taken into account the resistance of connected diodes and LED's because the three charges consist of the same resistance and the same diodes and LED's. This practice has a total of two switches, and a total of three options different: both switches open, one open and one closed, and vice versa. This gives us that can take a load of 20 kΩ, 15 kΩ or 10 KΩ. When the equivalent load is 20 kΩ (two loads of 10 kΩ in series), the intensity is such that:

$$I = \frac{V}{R} = \frac{230}{20000} = 11{,}5mA \quad (2)$$

The power to be carried on each of the resistors will be:

$$P_R = V_R \cdot I = I^2 \cdot R = (0{,}0115)^2 \cdot 10000 = 1{,}3225W \quad (3)$$

In this case, the power that each resistor has to endure is not a problem, since each of them is capable of handling with 10 W. Although as we know, testing time is limited as in all practices to avoid overheating, errors, etc.. When the equivalent load is 15 kΩ (10 KΩ load in series with two 10 KΩ loads in parallel), the intensity is such that:

$$P_R = V_R \cdot I = I^2 \cdot R = (0{,}01533)^2 \cdot 10000 = 2{,}35W \quad (4)$$

This power is still no problem with used resistors of 10 W. When the load is equivalent to 10 kΩ, the intensity is:

$$I = \frac{V}{R} = \frac{230}{10000} = 23mA \quad (5)$$

In this case, if just 10 kΩ resistance is used the power to be support will be:

$$P_R = V_R \cdot I = 230 \cdot 0{,}023 = 5{,}29W \quad (6)$$

This is the highest power which crosses the resistor in this practice, but it is still far away from maximum power, which is supported by resistor, 10 W.

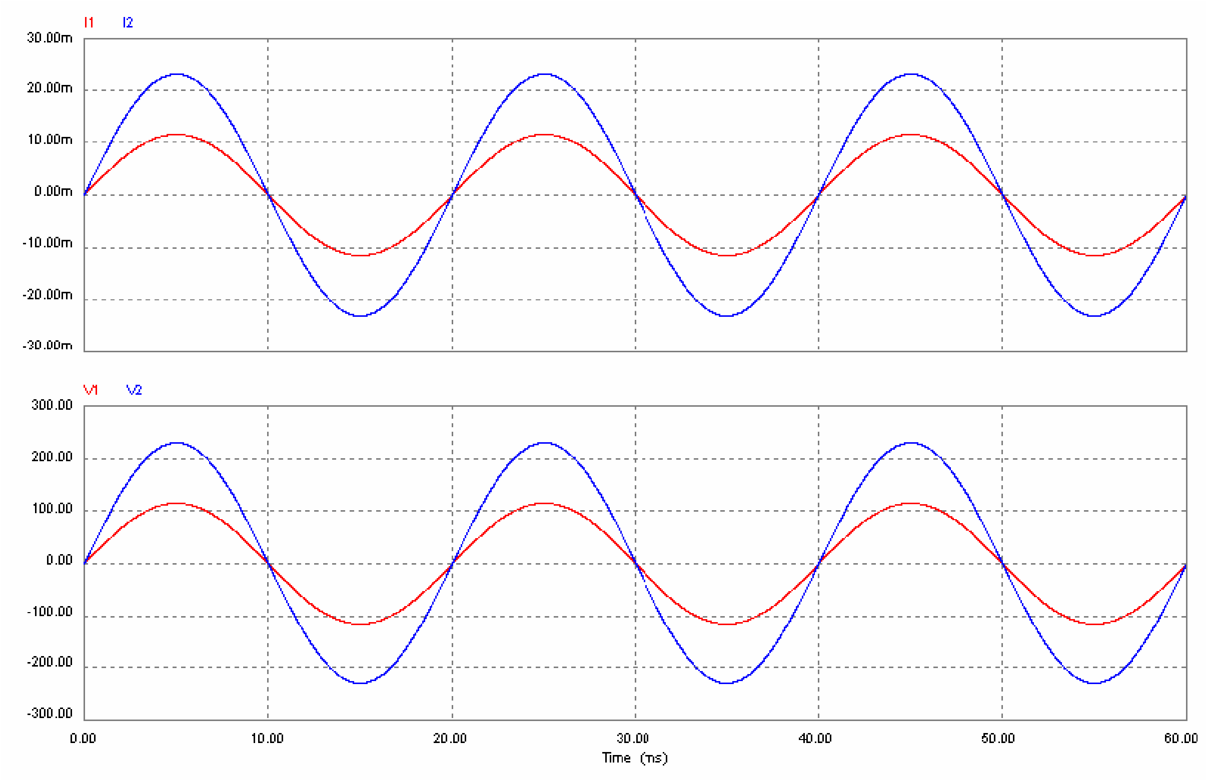


Figure 6.2. *Dips made by linear load practice.*

Figure 6.3. *Photo of linear load practice.*

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6.2. Single Phase Bridge Rectifier

The object of this project is the study of the harmonics created by nonlinear load. Harmonics in this practice are created by rectification of the alternating current with a single phase bridge rectifier.

The circuit consists basically of three types of elements: resistors, capacitors and a bridge rectifier. The bridge rectifier is responsible for converting the alternating current to continuous current. For bridge rectifier is characteristic, that between each peak of each half-wave create a range are the voltage decreases. To solve this problem we added a electrolytic capacitor, which act as filter. The intention was that the current ripple could be visualized by the Circuit Monitor. The circuit diagram that corresponds to this practice is shown in Figure 6.4.

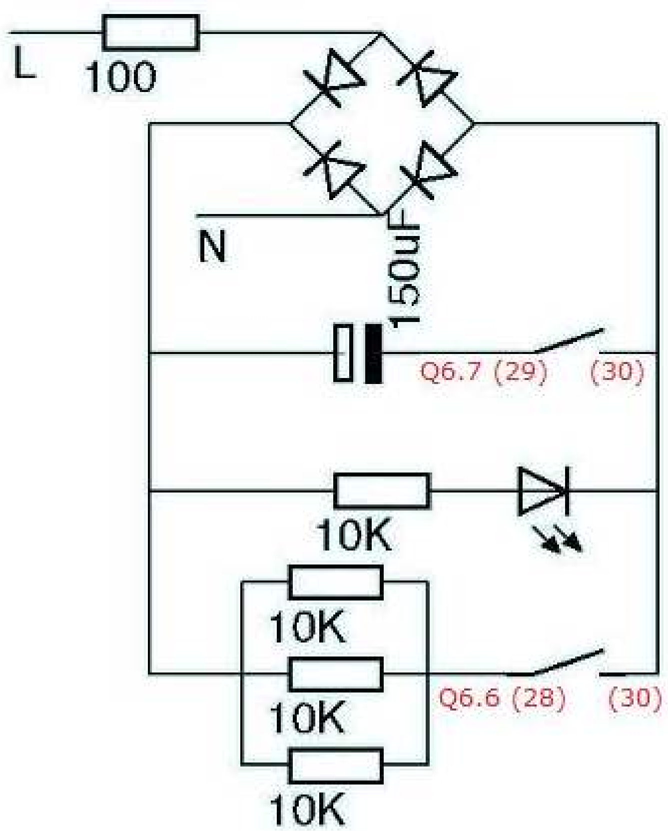


Figure 6.4. *Circuit diagram of single phase rectifier.*

Components:

- An electrolytic capacitor with 150μF,
- A 10 KΩ resistance in serie with an LED. This resistance is always connected, and if so will be activated LED with bright green color.
- A group of three resistors in parallel of 10 KΩ in series with a switch When this switch closes the circuit load will increased approximately four times.

In this practice is possibility to connect or disconnect the capacitor or add more resistances in parallel to increase the consumption, what will also affect the power quality. For this reason we used three more outputs of automat 28,29 and 30 as two switches. They corresponds directly to the outputs Q6.6 and Q6.7. First one to connect capacitor and second to connect additional load.

Calculations

Here are explained some necessary calculations to perform the test correctly.

As the supply voltage is 230 V RMS, it is necessary to calculate first Maximum voltage:

$$V_p = \sqrt{2} \cdot V_{ef} = \sqrt{2} \cdot 230 = 325V \quad (7)$$

The load consists of one or four resistors in parallel, each with a value of 10kΩ, thus obtaining an equivalent value of 2500 Ω. Knowing that must withstand 325V and its value is 2500 Ω, we have a current in the parallel:

$$I = \frac{V}{R} = \frac{325}{2500} = 130\,mA \quad (8)$$

The current flowing through each of these resistors is:

$$I = \frac{V}{R} = \frac{325}{10000} = 32,5\,mA \quad (9)$$

So we have consumption on each resistor:

$$P_R = V_R \cdot I = 325 \cdot 0,0325 = 10,56W \quad (10)$$

The resistors are prepared for a power of 10W, which, as the maximum time that practice can be activated is three minutes with two minutes rest at least the end of use, can be using this resistors without problem. Here we can see why the test time is limited, to prevent overheating of the resistors. On the test plate is placed also one LED. It is known that an LED has a potential difference of about 3 V and need intensity for proper operation of 10-40 mA. Knowing that the voltage flowing through that branch is 325 V and the LED consume 3 V, is a voltage of 322 V which will be consumed by resistance in series with the LED. This resistance of 10 kΩ countries and supports a power of 10 W.

The power consumed by resistor is:

$$P_R = \frac{V_R^2}{R} = \frac{322^2}{10\,000} = 10,37\,W \quad (11)$$

Current passing by LED is:

$$I_{LED} = \frac{V_R}{R} = \frac{322}{10\,000} = 32,2\,mA \quad (12)$$

Calculating the current passing by LED we can see that it is optimal for supplying LED.

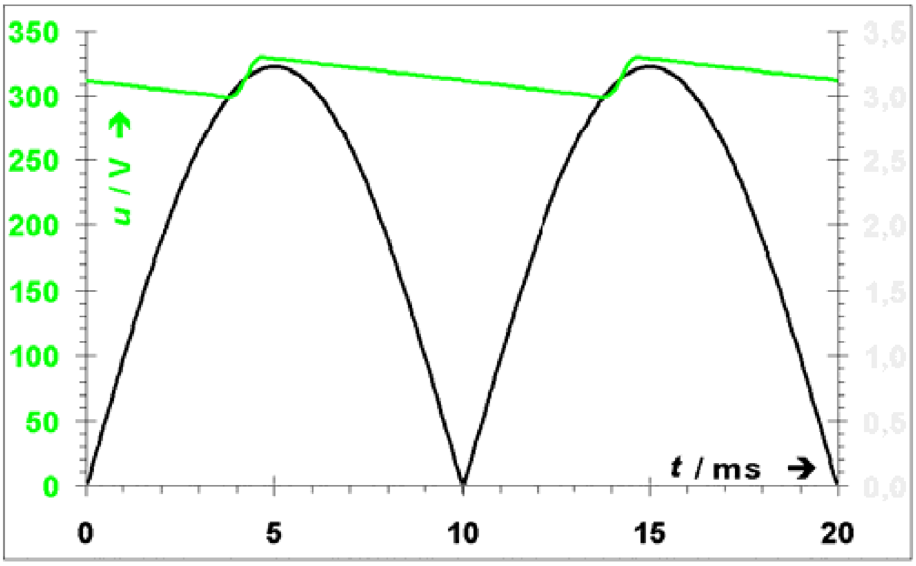


Figure 6.5. *Voltage chart of single phase rectifier practice.*

Figure 6.6. *Photo of single phase rectifier practice.*

6.3. Three-Phase Bridge Rectifier

The objective of this practice is the same as in the previous practice, with the difference that the circuit is performed three times on one circuit board, where each phase has its single-phase rectifier circuit. In this practice, there is just one output of automat that feeds the practice through three relays, corresponding each to a different phase. The capacitor and resistances are permanently connected. At the Figure 6.7. you can see the layout of the practice.

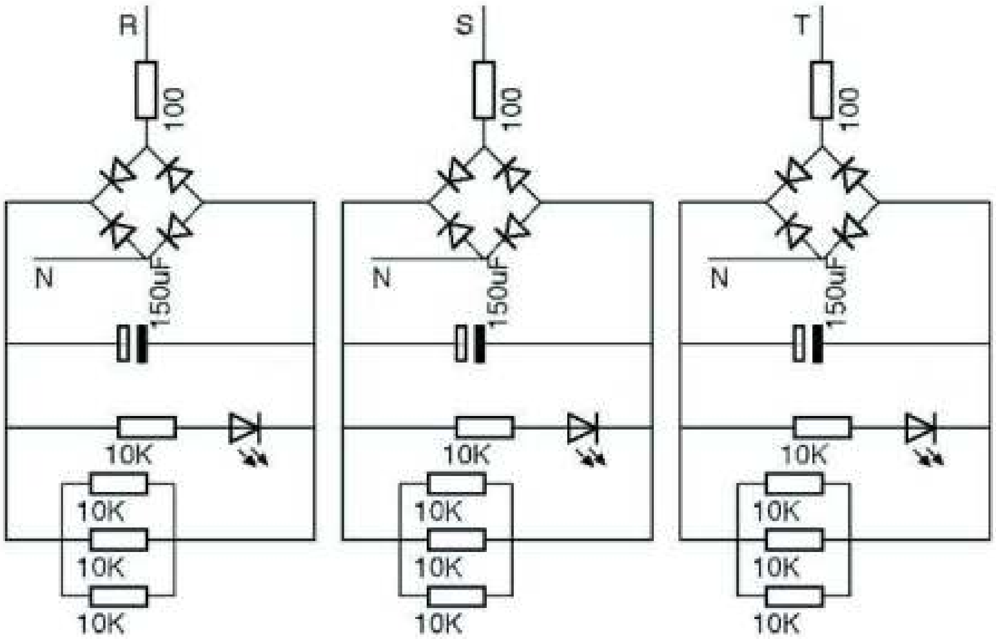


Figure 6.7. *Circuit diagram of three-phase rectifier.*

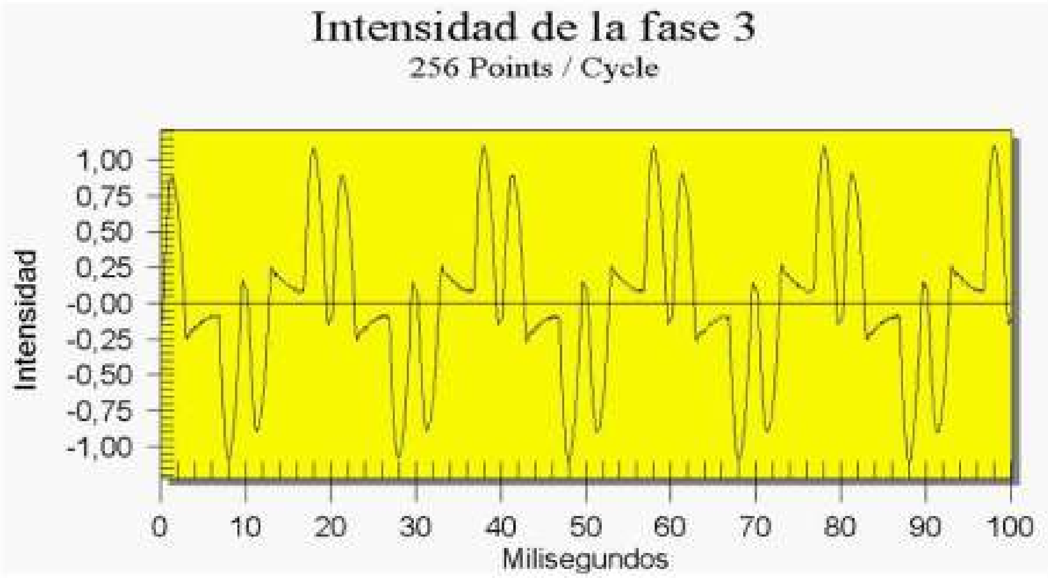


Figure 6.8. *Intensity chart of three-phase rectifier practice.*

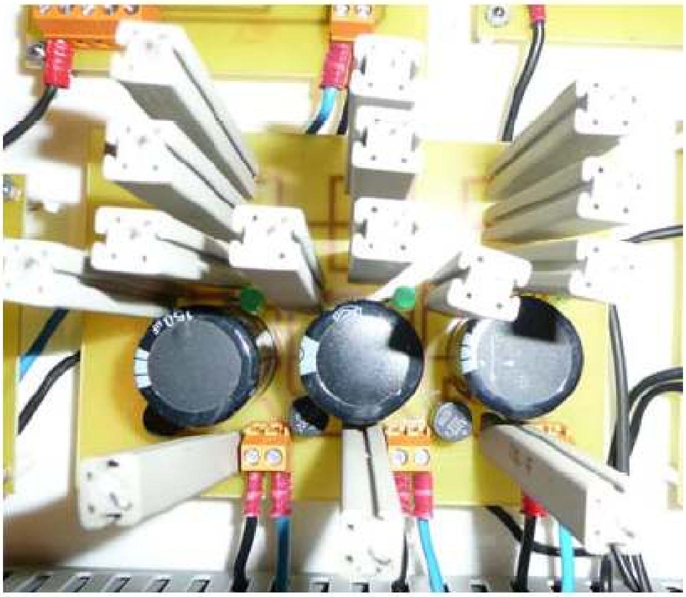


Figure 6.9. *Photo of three-phase rectifier practice.*

6.4. Energy-saving lights

The objective of this practice is to study of power distortion incorporated with energy-saving lamps and compare them with the power distortion of normal resistive bulb. There is also possibility to exchange them for any bulb light with edison screw. The diagram in Figure 6.10 corresponds to the circuit of connection of this practice. In this schematic has been detailed the connections with relays outputs of automat. As you can see in the image, the three lamps have the same scheme, and each is activated by a different output of the automat, as is indicated in the circuit. As in the another practices, there is a time limit, which is also three minutes and then at least two minutes of rest. In On the Web for this practice is the option of turning on anyone lamp or turn on two or three lamps, in any order, and because of this we can view, by the program SMS, harmonics produced by combination of this lamps. As has been repeated in other sections of this report, in this scheme, you can see how each relay are used two switches in series (to give more longlife to the relays), and as it is connected in parallel with 24 V input resistance of 2200 Ω at series with an LED. This LED always tells us that which relay is activated. The LED's related to this practice are yellow. To make it simpler to divide it from other practices and to make it more esthetic.

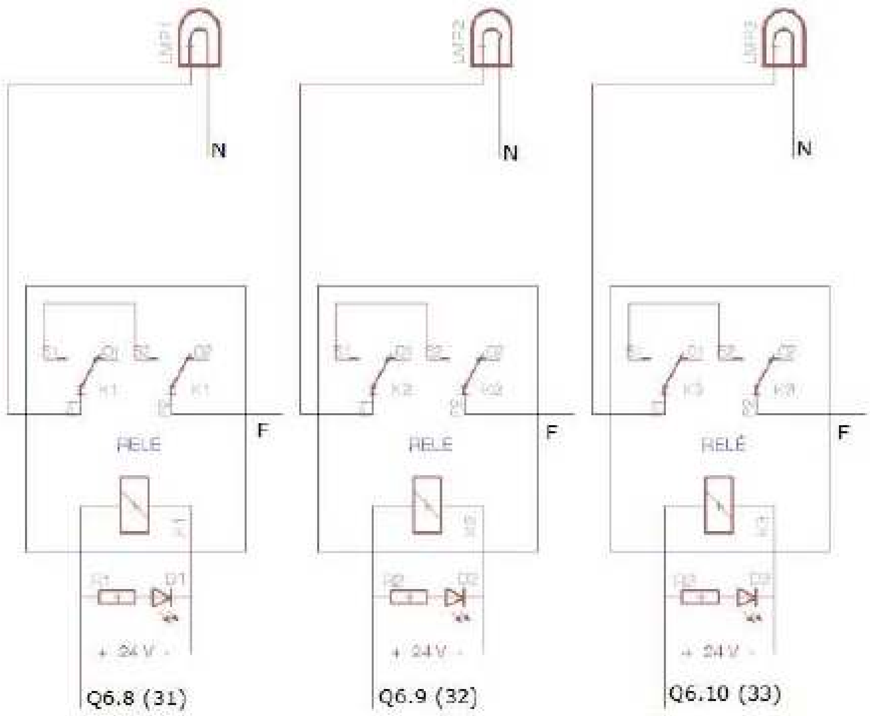


Figure 6.10. *Circuit diagram of energy-saving lights practice.*

On this figure we can se internal schematic of the energy-saving lights used in our practice. As we know it is switching device, which produce a lot of harmonics.

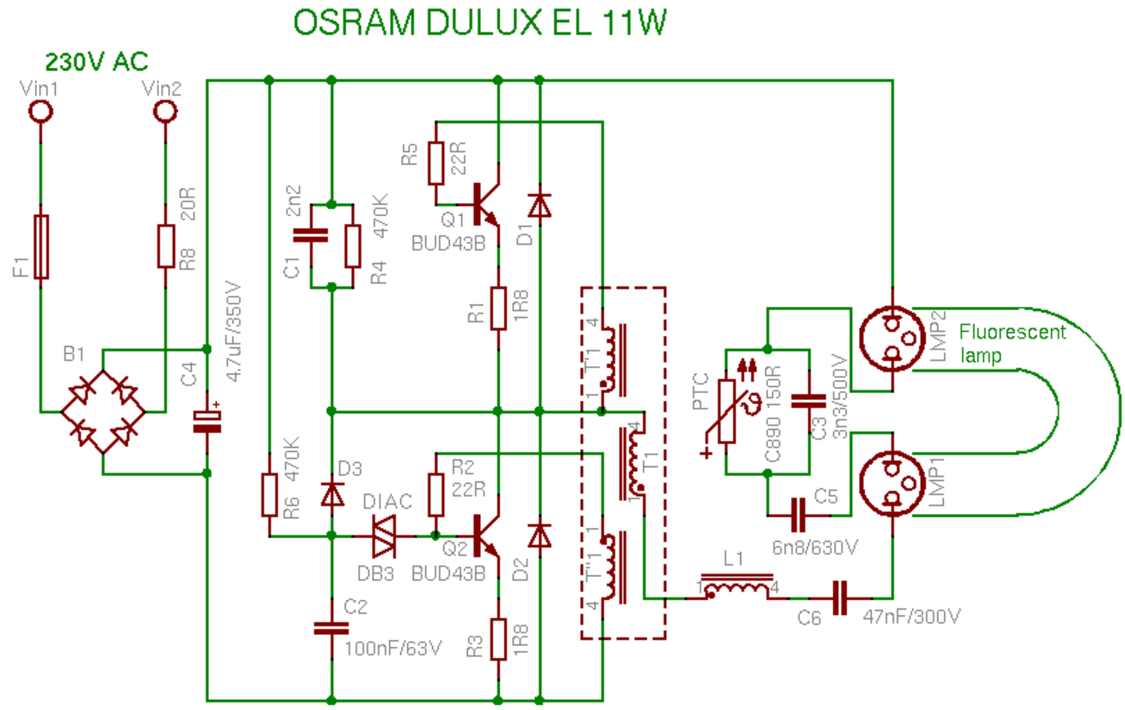


Figure 6.11. *Circuit diagram of energy-saving light.*

For installation of this practice, only it was necessary to calculate the current flowing through these lamps, since we had to verify that it is not too much for our small relays this value it could withstand relay, otherwise we will use a contactor. We know that relays support current up to 1,25 A. First we calculate current passing through energy-saving lights

$$I = \frac{P}{V} = \frac{11}{230} = 47,8mA \qquad (13)$$

We can see clearly, that these lamps will be no problem for our small relays.

Now we calculate current passing through edison light bulb.

$$I = \frac{P}{U} = \frac{60}{230} = 260mA \qquad (14)$$

It is much more than with the energy/saving lights, but still too small for our relays.

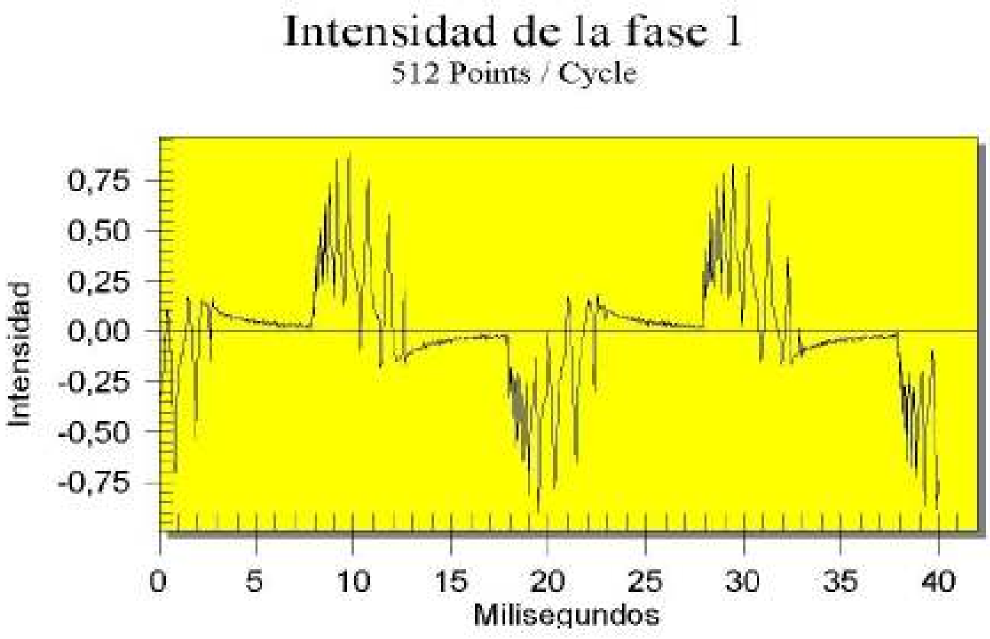


Figure 6.12. *Intensity chart of one energy-saving lamp*

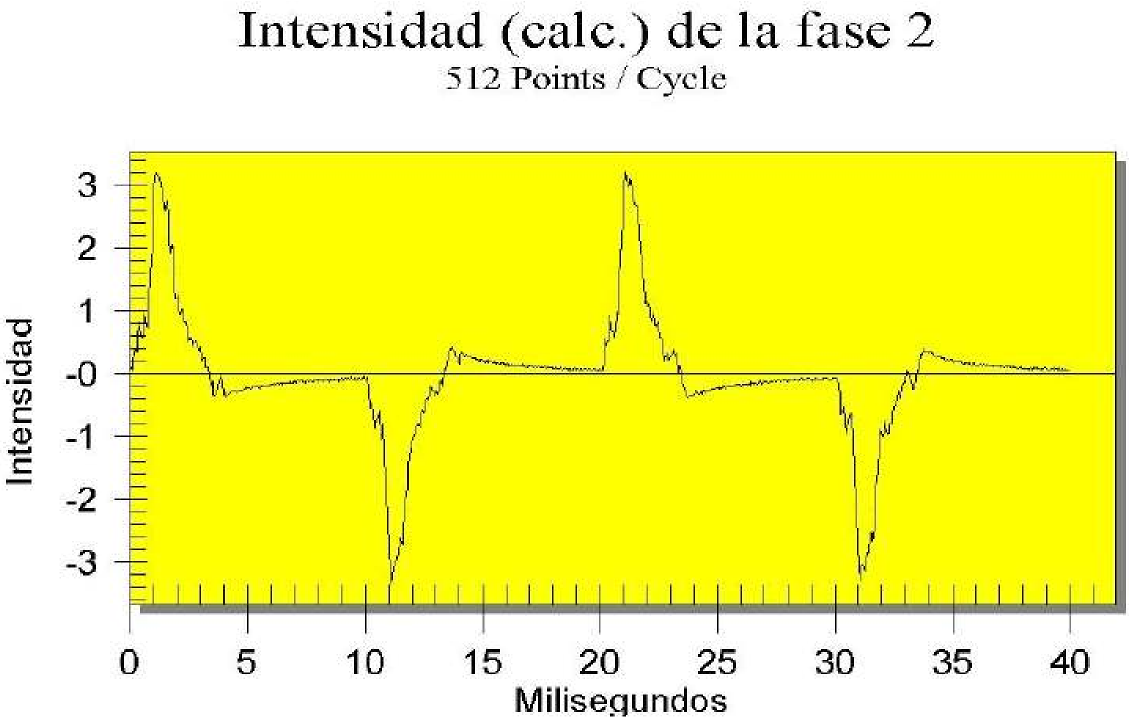


Figure 6.13. *Intensity chart of three energy-saving lamps.*

Figure 6.14. *Photo of energy-saving lamps practice.*

6.5. PC power source

In this case has been necessary to use a contactor, as the current required to operate power supply can not be supplied by a relay with Imax=1,25 A. The current flowing through the supply terminals of the power supply is according to manual 3 A. Because of metal chasing of PC supply there are three wires connected to the supply, phase, neutral, and ground. We also disconnected the electric plug on the PC source to prevent from any accident by touching it As with all the practices, the activation of this test is performed through its website, and maximum duration time is three minutes, two minutes rest minimum. The source of a PC is a nonlinear load that introduces many harmonics, which are easily collected with our network analyzer, Circuit Monitor 4000. On the next figure you can see the internal schematic of power supply. It is clear that this complicated high frequency source will have a big influence to the power quality.

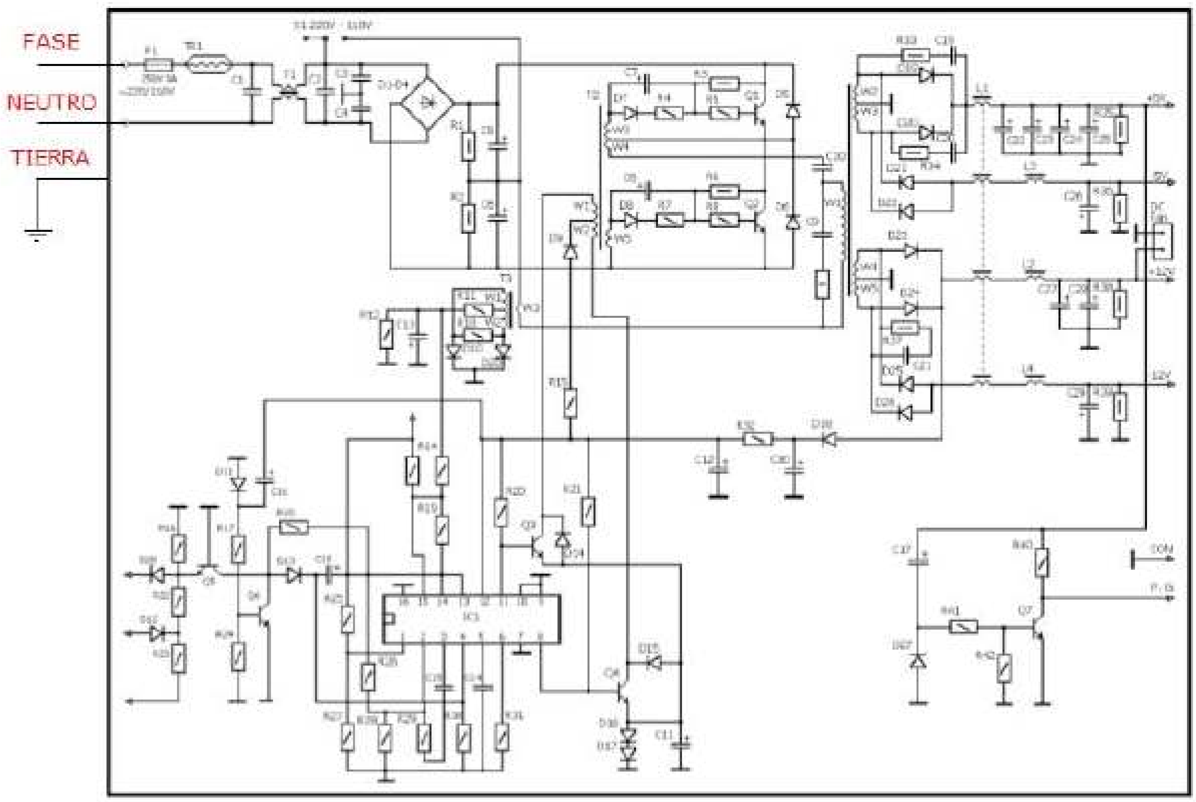


Figure 6.15. *Circuit diagram of PC source practice.*

There was not necessary any calculations, as we can find the current passing by source in datasheets and it is 3A.

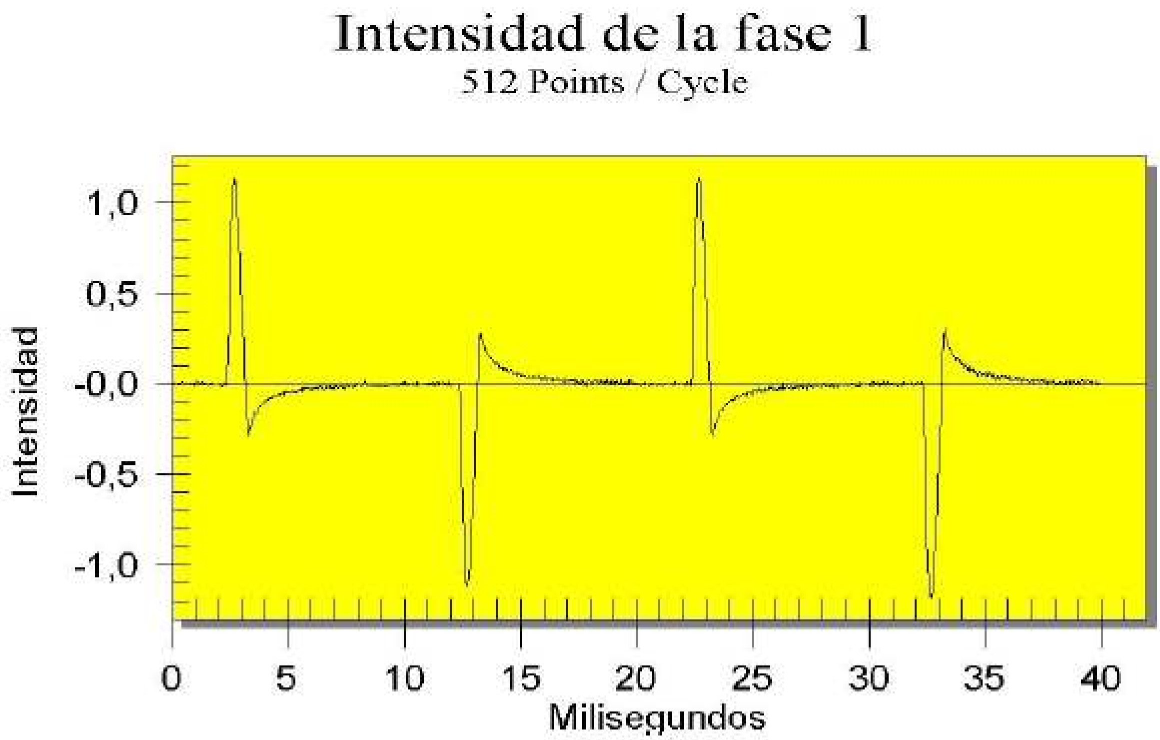


Figure 6.16. *Intensity chart of PC source*

Figure 6.17. *Photo of PC source practice.*

CHEAPTER 7: UPGRADE OF THE LABORATORY

Despite that till now two students have been working on this project, still wasn't finished. Still had some limitations which have been removed. The different objectives to achieve were following:

- Add the new practice of three-phase motor variable speed driver. This will produce a range of harmonic distortion.
- Add plug to connect and measure the influence of any electric devices. This make the laboratory more flexible and able to measure the harmonics of any appliance.(for example transformer, arc welder, fluorescent lamps, devices controlled by thyristors, rectifiers, inverters, static compensators, cycloconverters, HVDC transmission)
- Improve the web interface to be more user friendly, and intuitive to control. Also add new languages to the web site to make this project more interesting for the students from all over the world.
- Create the new program for the PLC TSX Micro 3722. This will be necessary after the adding of new practices. That will be incorporated into the remote laboratory.

7.1. Plug

This practice is a new addition to the remote laboratory. It is normalized CEE7/4 electrical plug, used in mostly in the EU countries. Only complication with assembly was drilling, nailing, adding a small conductor cover, screwing the plug, and peel and ferrule cables. The plug should be universal and able to be used for all types of devices. That is why we used in this practice the ground wire. We also used the contactor instead of relay, because with relay will be able to support the devices with consumption up to 287,5W but with contactor we can use devices with consumption up to 2kW.

Figure 7.1. *Photo of electric plug practice.*

7.2. Variable speed drives

In this practice we used the variable speed drives Hvac Altivar 21H075N4 with 0,75kW/1HP output. To connect this practice we used contactor instead of relays for two reasons. First is that this is three phase device and second was that the current consumption is, according to data-sheet, 1,7A.That is too much for our small relays. The connection of this device was so simple that it is not shown on separated figure. We connected all the three phases through the contactor to the inputs of the device and programmed automat to switch contactor with associated command. We connected the ground wire to the device, because it aluminium chase could be dangerous in case of accident, if it is not grounded. Of course this wire will not be disconnected by the contactor. We programmed the Altivar 21 to launch the governing program directly when the driving voltage is connected to the input. This is controlled by setting the parameter F301.

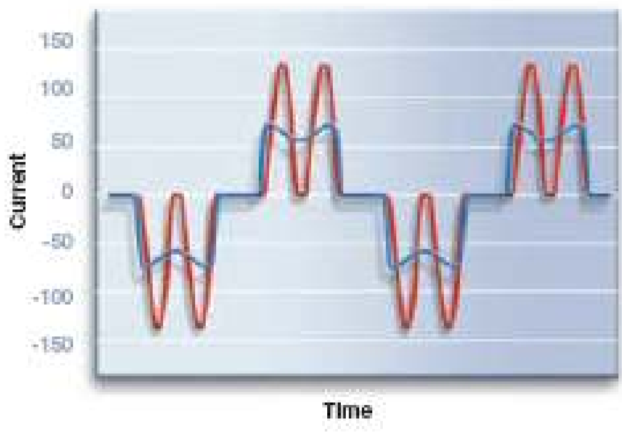


Figure 7.2. *Intensity chart of variable speed drives*

Figure 7.3. *Photo of variable speed drives practice.*

7.3. Three-phase transformer

This is second new three-phase practice connected in this laboratory. In this practice we used transformer with big impedance to see the harmonic distortion made by this device. There is also possibility to manually change windings of the transformer.

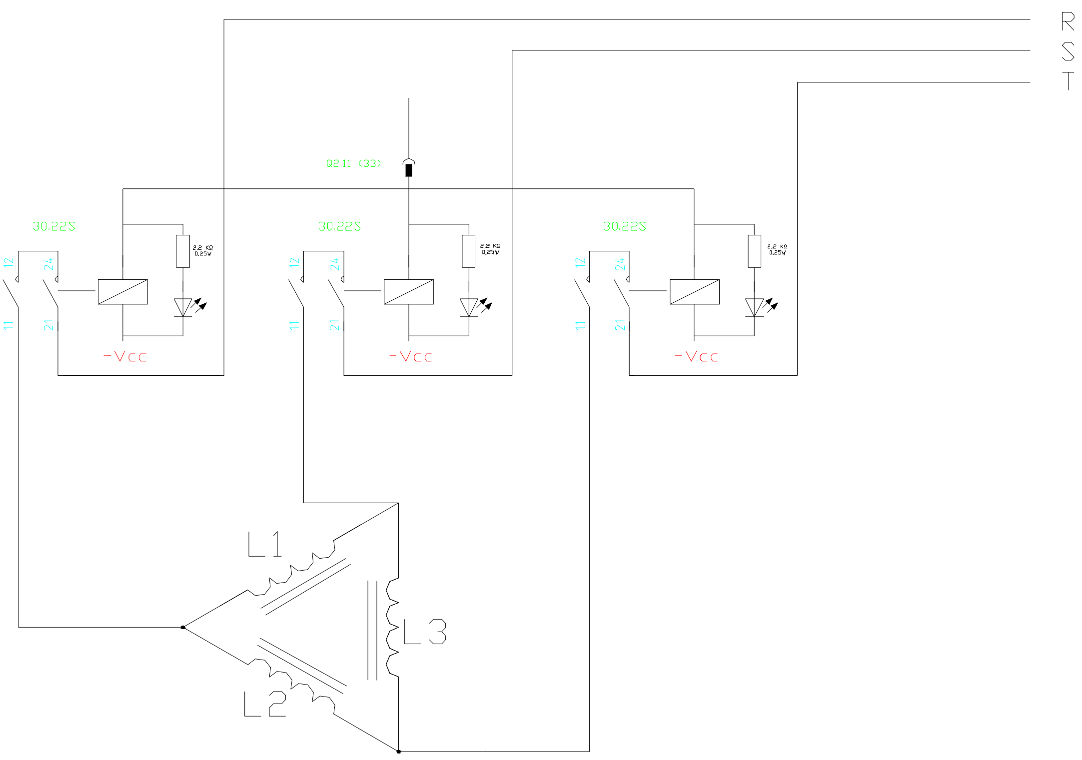


Figure 7.4. *Connection diagram of transformer practice.*

We again have to make certain that current passing by transformer, is small enough connect transformer through small relays, or we need to use contactor. Because there is not any marking on this transformer, we had to measure the current passing by the coils. We found out that current is below 1A and as we know limit of relays is 1,25A. However because it is three-phase transformer we have to use three relays, one for each phase.

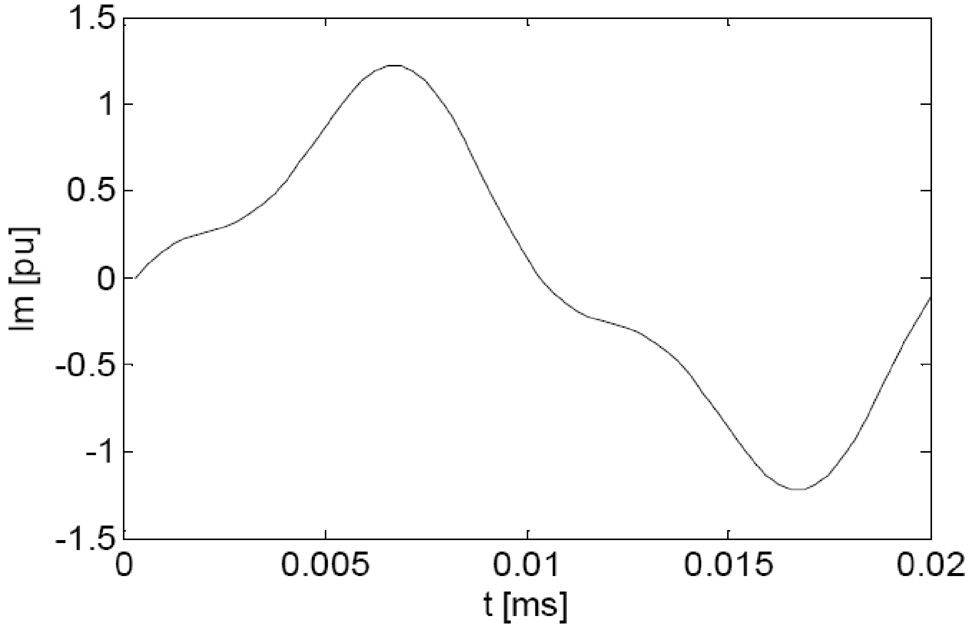


Figure 7.5. *Intensity chart of transformer*

Figure 7.6. *Photo of transformer practice.*

Figure 7.7. *Complete laboratory*

CHEAPTER 8: CONFIGURATION AND PROGRAMATION

For proper operation of the remote laboratory we have programme the PLC by Factory Cast through the wired connections. To begin, we must connect the network card with a crossover cable to computer and set up the IP address of the computer to the same as the IP of new network card. To configure this you should click on the icon "Connections to local area "and the IP option, properties and change this information as you can seen in Figure 8.1. Once you made this, go into the website of the card which still has IP defined by the producer. Within this site there is the option to change the IP. At that time should be replaced by the existing IP which will be assigned to the remote laboratory. This step is shown in Figure 8.2. Factory Cast and as well the PLC must have an IP that is in the same domain, i.e. match all IP less last three numbers.

The IP address of the automat in our remote laboratory is:

http://147.83.169.224

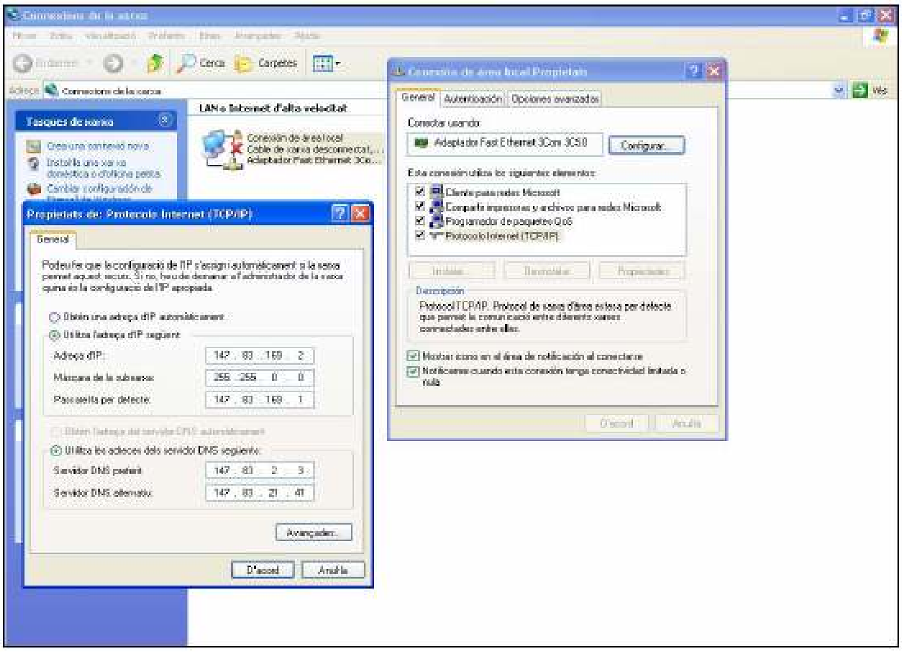


Figure 8.1. *Changing of IP address*

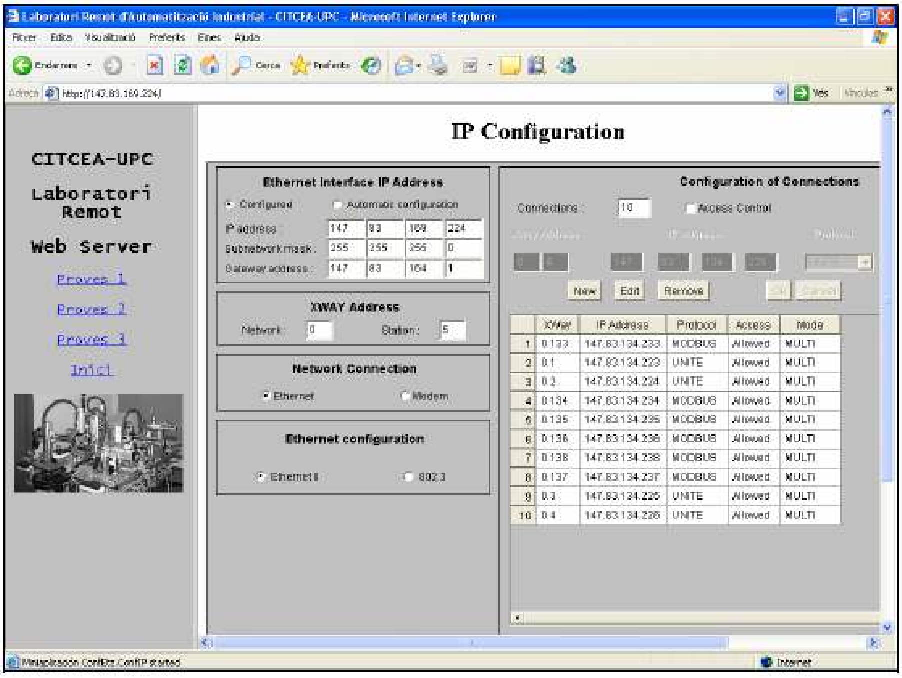


Figure 8.2. *Setting of new IP address*

8.1. Programming of the PLC.

To program the PLC practices, has been used the program Telemecanique PL7 Pro v4.4. To make the program work with practices the following steps have to be followed.

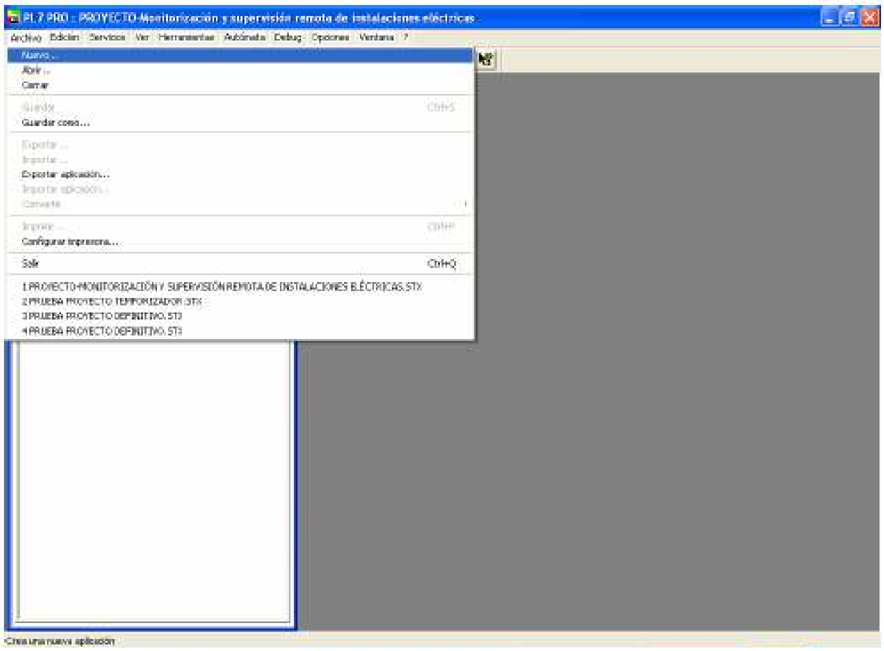


Figure 8.3. *New program in PL7*

To create a new program you have to select the type of automaton with which you will work. In the case of our remote laboratory the TSX Micro PLC 3722 v6.0 is used.

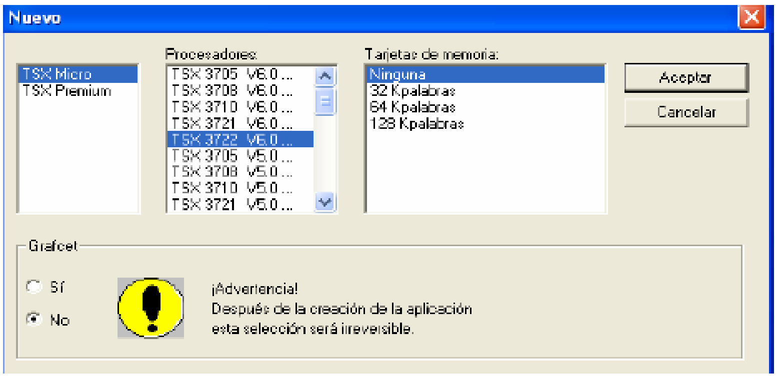


Figure 8.4. *Selecting automat*

Then we go to the next step for software configuration. We will select the card inputs / outputs which we have in the program. In the case of our remote laboratory will to select the blocks 5 and 6 where is DMZ card 28 DTK, and Boxes 1 and 2 where is TSX DSZ 32T2 card from which we will use only outputs as shown in Figure 8.5.

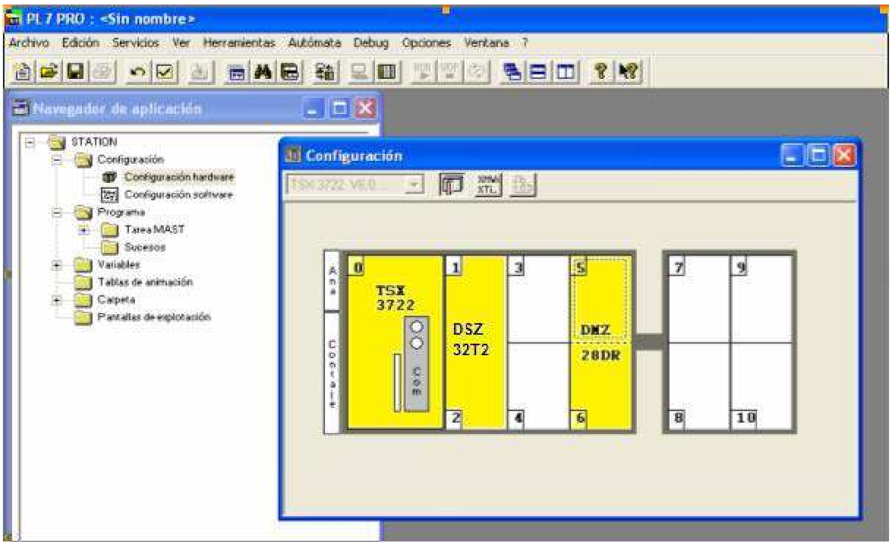


Figure 8.5. *Selecting cards*

Then continue to the creation of a section, where you will choose language with which the program will be made and put the name of the project in. We choosed the ladder language (LD) as it is more user friendly. Once we have done this, we can start programming.

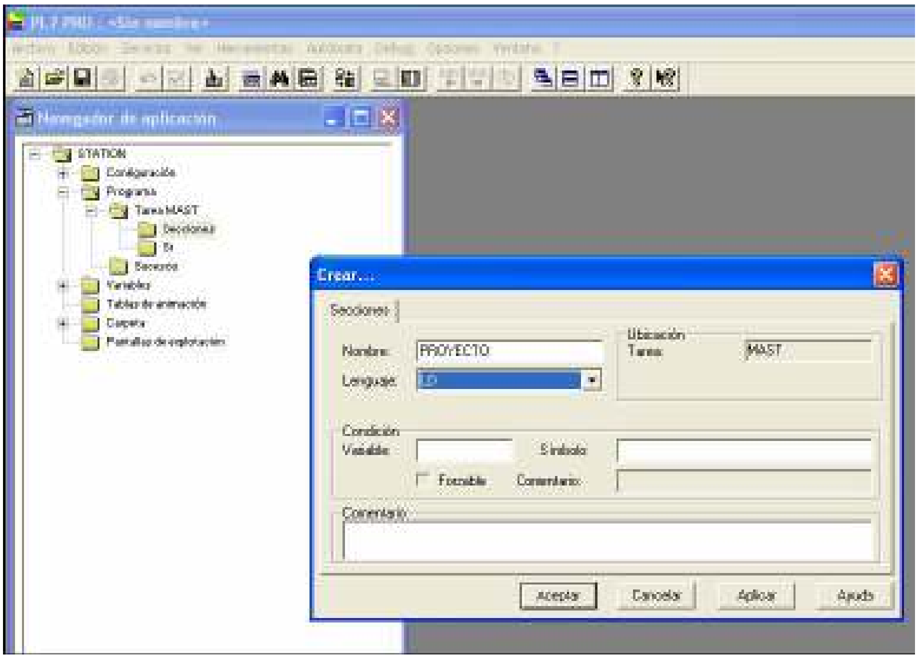


Figure 8.6. *Selecting of the language.*

8.2. Programming in Ladder language.

The whole program is attached in the annexes and here is explained just the function of program in the Entity relationship diagram.

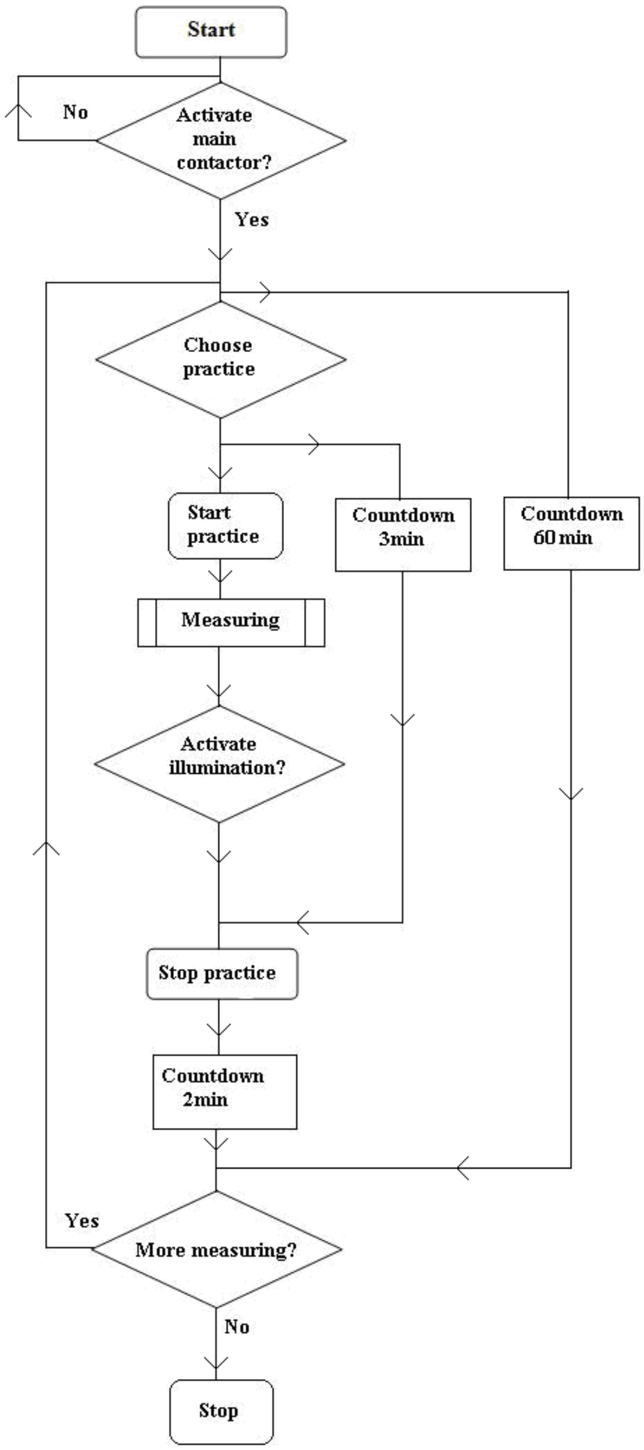


Figure 8.7. *Entity relationship diagram*

In order to activate any practice, you have to activate first main contactor which is governing all the practices with the power supply.

Than you have to choose the one practice you would like to work with.

Together with starting the practice the countdown timer is started. This timer is added to avoid overheating and mistakes of measuring. It will guarantied, that the practice will not be working longer than three minutes.

During measuring in the laboratory, the illumining bulb can be activated, if the measuring is done during the night.

You have to stop practice on which are you working, and just than you can start to work on another practice.

If the countdown timer pass and stops the running practice, you have to wait 2 minutes to be able to work with the practice again, this time is adequate to cool down the practice.

There is also one timer more, counting to 60 min which turn off the main contactor after one hour. This timer is added just for security reasons.

8.3. Programming of the web interface.

As mentioned above, through the IP network card can access the page of the automaton, as shown in Figure 8.8.

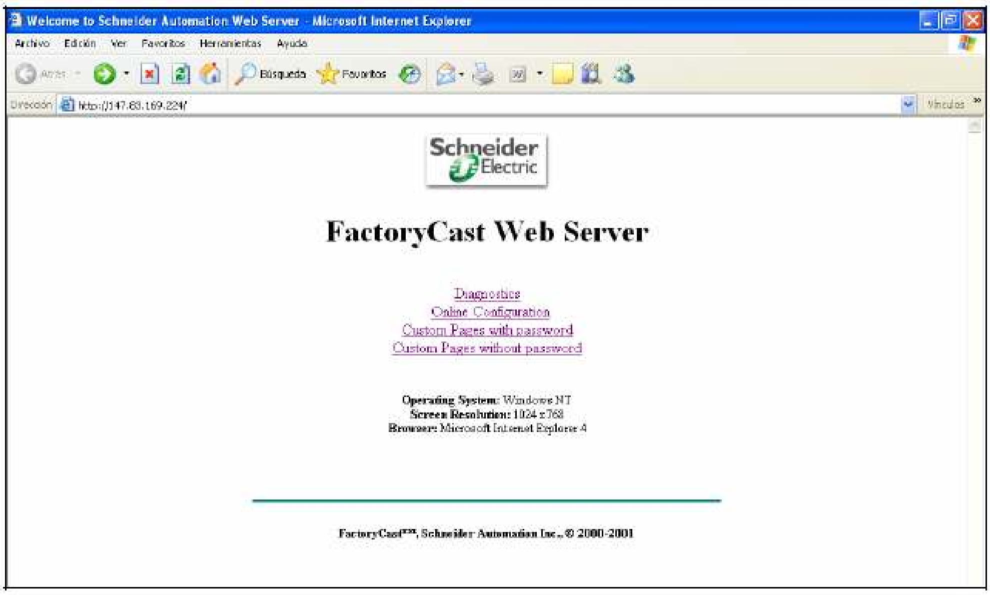


Figure 8.8. *PLC front page*

To work with the practice as an user we click on the Diagnostic, and put down the user name and password, to connect to the PLC web pages.

Than the next page is shown with options of diagnostic.

For the regular user of the laboratory is important just the options of the Graphic Editor. This is gate to laboratory-user interface.

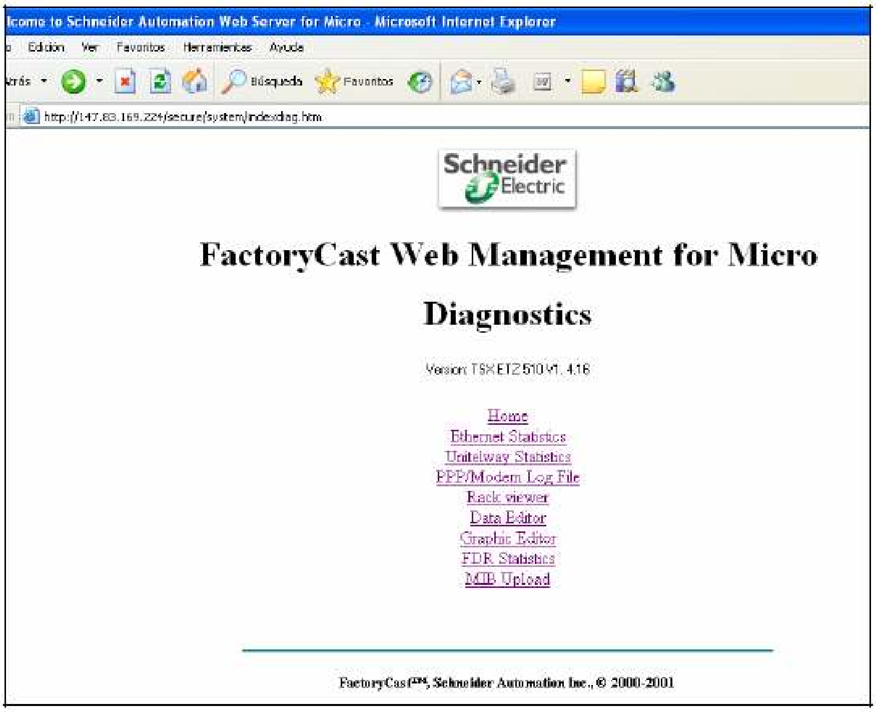


Figure 8.9. *Diagnostics page*

We have created here sixteen pages for eight practices. Each practice has its own web page in Spanish and another in English, for making this laboratory more international. For each practice, it has a corresponding control panel, which has buttons, red or green meaning OFF or ON and small amount of text to suggest functions of each button. There is also buttons for activate main contactor and illumination of laboratory. On each page are also three timers showing us how much time we have to work, wait or till the illumination will turn off. Once selected the practice to be manipulated, simply by the buttons displayed in the window are selected options of choosed work. To change practice, we will only by using the dropdown menu select the next practice we want to use. The following images are displayed on the control panel of practices if you choose practices in English.

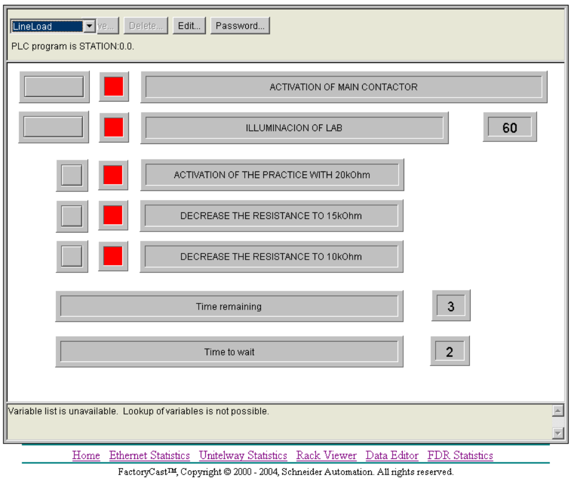


Figure 8.10. *Linear load*

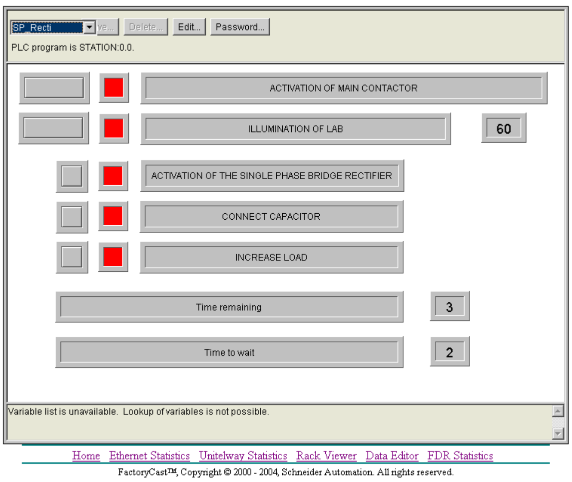


Figure 8.11. *1.Rectificador*

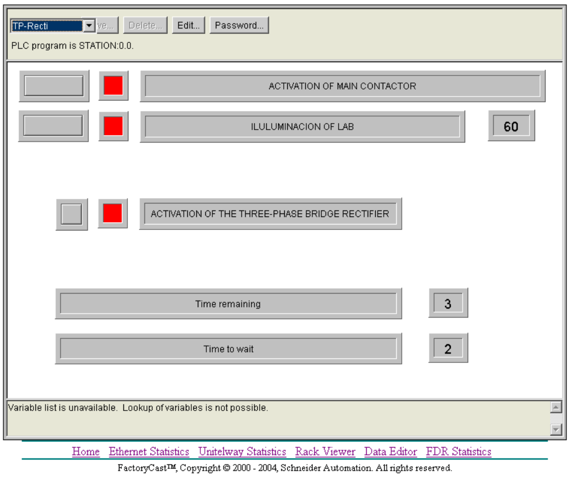


Figure 8.12. 2. Rectifier

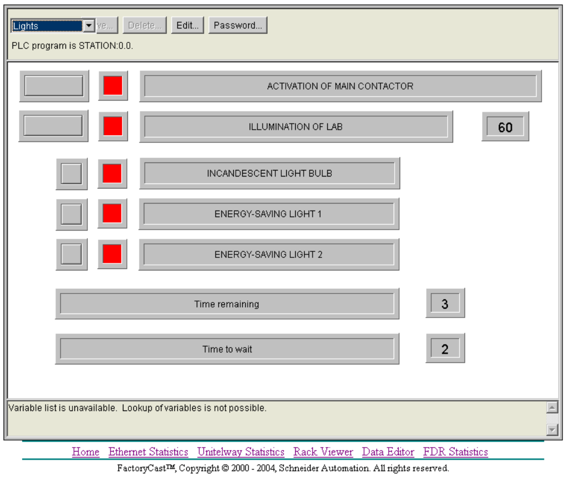


Figure 8.13. Light bulbs

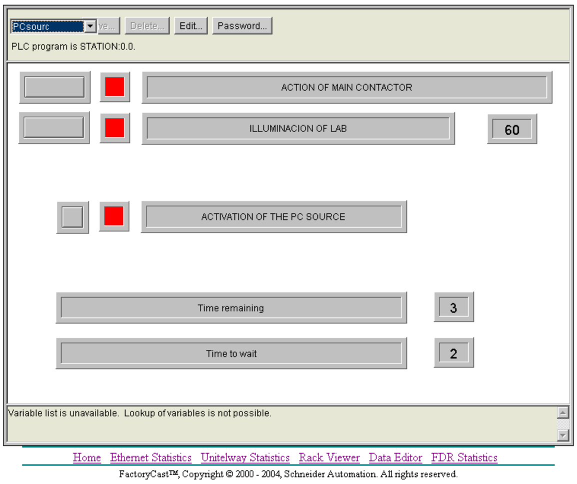


Figure 8.14. PC source

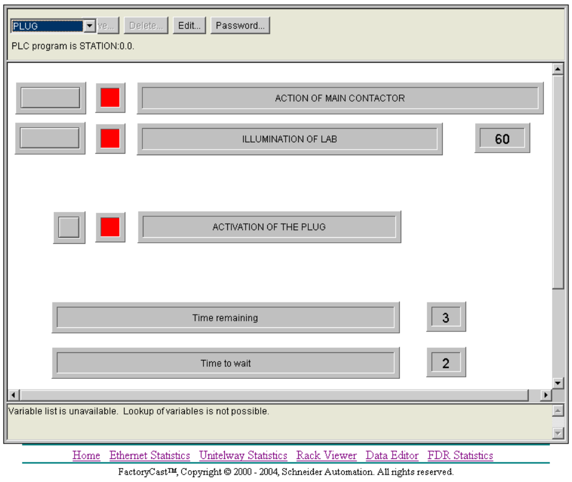


Figure 8.15. Plug

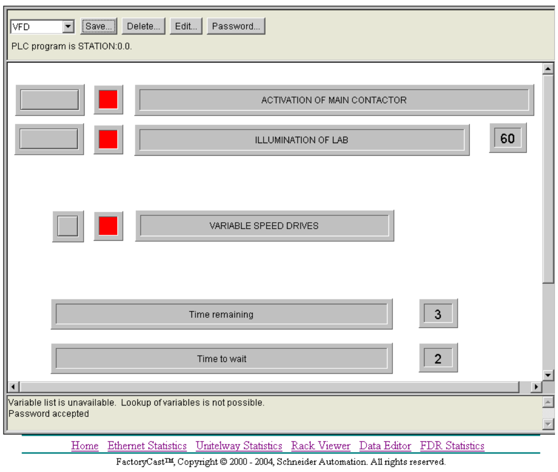


Figure 8.16. Variable speed drives

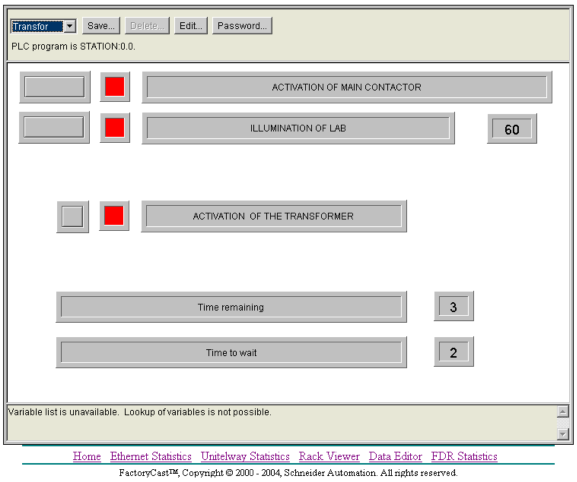


Figure 8.17. Transformer

CHEAPTER 9:

MEASURING SOFTWARE

9.1. SMS 1500

System Manage Software 1500 is a software for analysis of power quality. SMS1500 has an architecture designed to be installed on computer and perform measurements of various devices connected. SMS can communicate with different devices over the network, such as Circuit Monitor, Power Meter, Low voltage circuit breakers and Masterpact Compact, protection relays Sepam and generally any device that uses the Modbus protocol.

Functions of SMS1500 are:

- Data Table, meters and bar charts; It offers the possibility of display real-time data from different viewing tables, gauges and graphs of the readings made by equipment connected. You can also create custom user tables in.

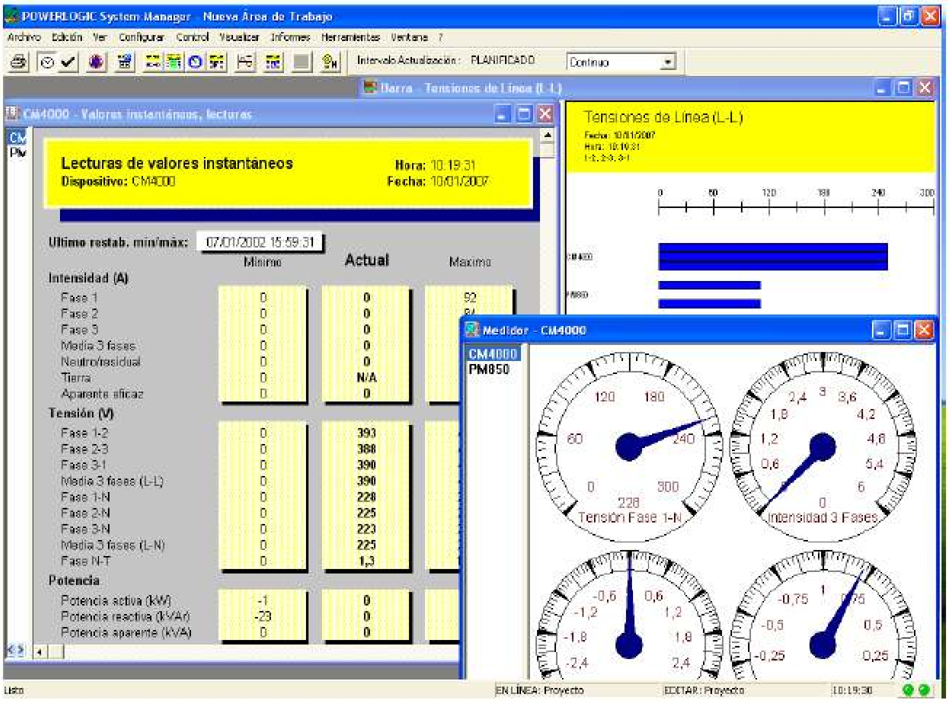


Figure 9.1. *Data table*

- Data and historical trends; The program stores all data recorded so that later studies of trend and graphics can be made.
- Display waveforms and harmonic analysis; Can display waveforms of voltage and current, simultaneously or independently each. Also harmonic analysis can be performed with the offered tool.

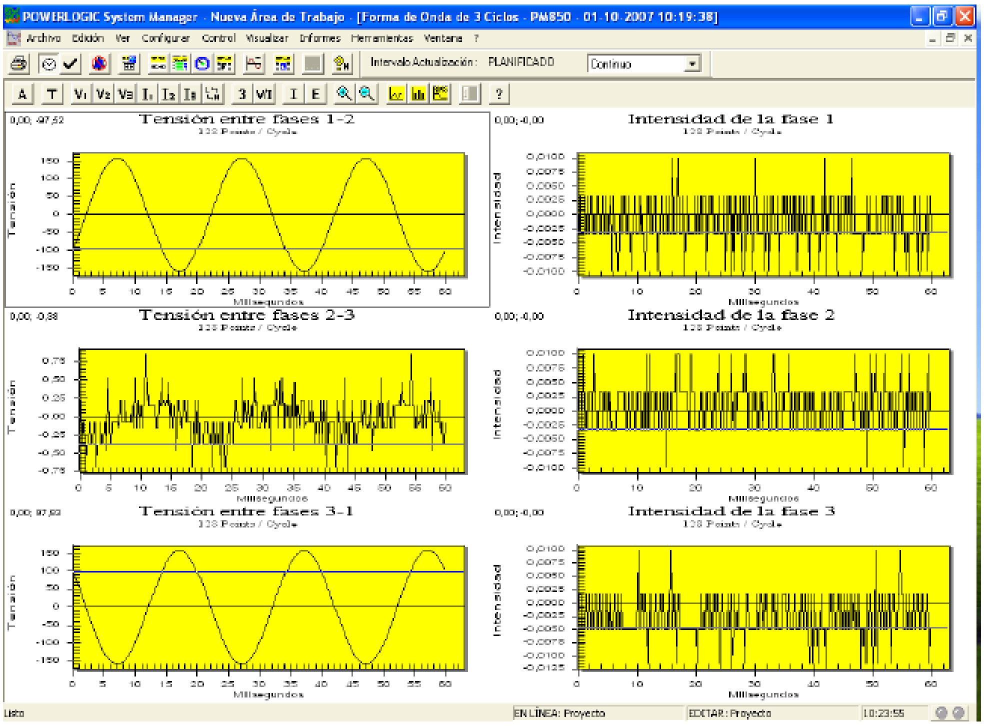


Figure 9.2. *Waveform*

- Event Log; It offers a great opportunity to record events linked to the alarm, the program tells us when an unexpected event occurs, a change in variables or communications failure.
- Dynamic Data Exchange; An important feature that has, is that data can be exchanged for other applications, such as Excel, to perform further analysis of reports and charts.
- Automated Tasks; The user may provide some variables and time specific in which the program will perform a series of records. These records can be captured as waveform or as an data.
- Create reports; Using this function, the user has a reports with all data.
- Other duties; There are other management functions such as user rights, control of equipment, organization of devices into groups and support systems.

9.2. Web interface

This device is equipped also with ECC21 communication card which can store up to 10 web pages each up to size of 500 Kb.

After entering the password we can do on-line measurement without any special programs, just with standard web browser. In the front page we have menu with the options of measurement.

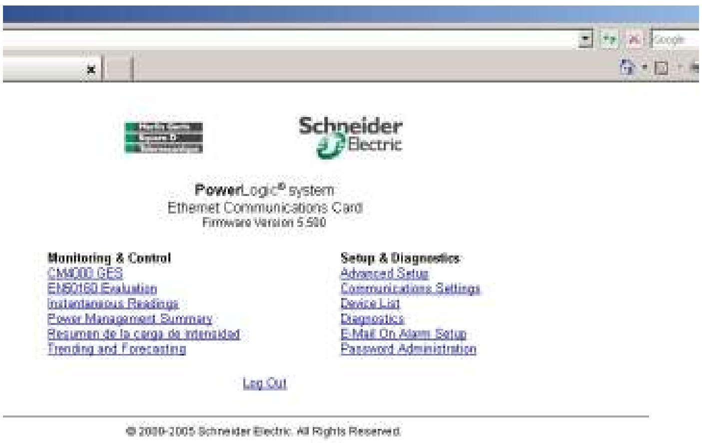


Figure 9.3. *Web front page*

Here are some examples of the measurements done by this interface. Such as measuring the frequency of power supply, current, voltage, voltage decreases and so on.

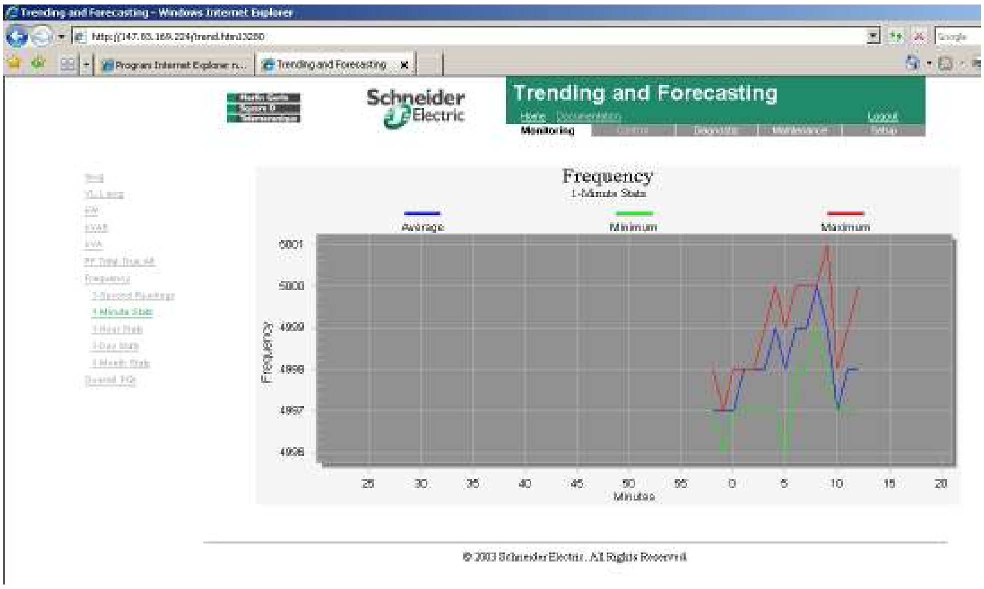
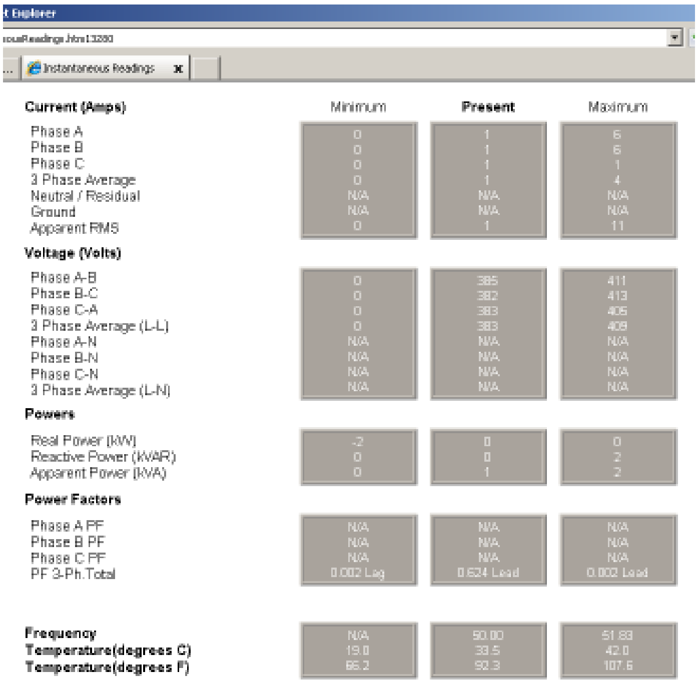


Figure 9.4. *Frequency chart*



	Minimum	Present	Maximum
Current (Amps)			
Phase A	0	1	6
Phase B	0	1	6
Phase C	0	1	1
3 Phase Average	0	1	4
Neutral / Residual	N/A	N/A	N/A
Ground	N/A	N/A	N/A
Apparent RMS	0	1	11
Voltage (Volts)			
Phase A-B	0	385	411
Phase B-C	0	382	413
Phase C-A	0	383	405
3 Phase Average (L-L)	0	383	409
Phase A-N	N/A	N/A	N/A
Phase B-N	N/A	N/A	N/A
Phase C-N	N/A	N/A	N/A
3 Phase Average (L-N)	N/A	N/A	N/A
Powers			
Real Power (kW)	-2	0	0
Reactive Power (kVAR)	0	0	2
Apparent Power (kVA)	0	1	2
Power Factors			
Phase A PF	N/A	N/A	N/A
Phase B PF	N/A	N/A	N/A
Phase C PF	N/A	N/A	N/A
PF 3-Ph.Total	0.002 Lag	0.624 Lead	0.002 Lead
Frequency	N/A	50.00	51.83
Temperature(degrees C)	19.0	33.5	42.0
Temperature(degrees F)	66.2	92.3	107.6

Figure 9.5. *Data table*

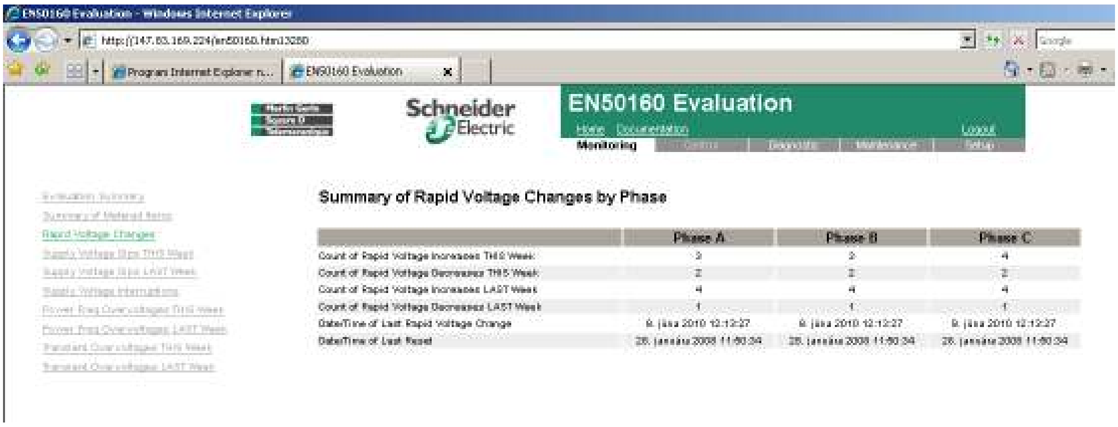


Figure 9.6. *Rapid voltage changes*

CHEAPTER 10: POSSIBLE FUTURE UPGRADE

This laboratory passed a long way since its inception. So the possibilities of the upgrade of the hardware is now very limited. However there are still some possibilities which are mentioned here.

On the automat have still 12 free outputs, to which can be connected new practice

Also there are four free relays to which can be connected easily new one phased practices.

The amount of the devices which are not working with linear load, and so have a influence to power quality, are these days a big amount, as they are mentioned in the chapter of the Power Quality.

It is also good idea to add possibility of connecting of active and passive power quality enhancers (capacitors, coils, etc.) to each practice, as the automat have enough outputs to support this. With possibility of monitoring of their influence to the power quality.

Also there are some possibilities to upgrade the practices, made by me.

- With variable speed drives there is possibility to improve this practice by connecting some outputs of automat the terminal plate of Metasys N2 card. This will enable to control the program of the drives to turn on and turn off speed controlling program. There is also RS485 communication port though which it could be programmed to change the working frequency and monitor the influence of this action to the power quality.

- With transformer there is also possibility of improve. For example, because this transformer has 4 separated windings there is possibility to switch power supply to different windings. The next option is to add three relays to optionally connect some load to the output of the transformer and monitor the influence of this action to the power quality.
- The practice of electrical plug is variable by itself, because any device could be connected if is equipped with standard CEE 7/7 or CEE7/4 plug.

The biggest possibilities offer side of software used in this laboratory. There is missing for example one complete web page which will incorporate control part of automat, monitoring part of the PowerLogic system, and visual part of present web cam, amplified with explication of the theoretical part of power quality measuring and it influence. This upgrade was impossible because of lack of internet connection and static IP address in the laboratory.

CHEAPTER 11: CONCLUSIONS

Objectives of this project were the study of the quality of electricity supply, study of different existing remote laboratories, but main objectives was modification of existing practices in the laboratory, extension the lab with new practices, new web page design of the remote laboratory and also translation of project and web pages to English to ministry to spread possibilities of use.

During the PFC1, the theoretical basis was made as well as studied opportunities for improvement and expansion of the laboratory during the PFC2 period. First, was necessary to define the power quality. The most used normalization in European Union is EN 50160. This and many other resources have been studied. This have been simplified in the first part, to make this article understandable also for laic. The next step was to obtain information on remote labs existing in the network. A lot of different remote laboratories have been mentioned to explain disparate possibilities of application of remote laboratories. Once that the objectives purely theoretical have been made, it was necessary to focus on the main part, to upgrade remote laboratory and expand the lab with new practices. In this part the three new practices have been installed: variable speed drives, electric plug and three-phase transformer. For proper operation and control of the laboratory, it has been set a automat language LD (Ladder diagram), and configured and designed a few pages Web FactoryCast control in Spanish and also in English.

This laboratory offers several possibilities, as it may be used in practical education in school, to make a practices which are not normally done, because there are not too many laboratories that focus on the study of power supply, also with advantage of working on distance thanks to the control through Internet. This remote laboratory can be very useful for university courses related to the topic of quality power, or remote working.

CHEAPTER 12: REFERENCES

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