Education Enhancement on Three-Phase System Measurements

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Abstract: - Training on measurements to determine the characteristics of three-phase electrical systems is very useful for a deep knowledge of the theoretical aspects. Laboratory sessions for measurement by using advanced technologies must be performed in the training activity. Two implemented tools are presented.
In the first one a virtual instrument is implemented, it can be used in distance learning sections: the system includes electromechanical instruments for a better understanding of the system operation.
The last tool provides different features from the previous one; moreover, it can be realized as an electronic power meter, active and reactive, in a wide range of values.

Key-Words: Training on three-phase system measurements, Electromechanical instruments, Digital instruments, Virtual instruments, Micro-controllers, Advanced technologies.

1 Introduction

Real experiments with electric and electronic component and circuits, carried out by using advanced instrumentation, are relevant to accurate training and to provide a better feeling to undergraduates about measurement procedures and measurement system design [1, 2].
Training on measurements to determine the characteristics of three-phase electrical systems is very useful for undergraduates in the electrical engineering area: in fact, they can achieve an excellent knowledge of various theoretical aspects of the working in different load conditions, as a suitable introduction to the power system study.
For this reason, adequate laboratory sessions are needed, but there are some technical difficulties to overcome.
The settlement of a three-phase measurement station, designed for training, requires a careful choice of adequate components, among them the three-phase load with proper values of the electric quantities, the instruments with appropriate ranges; additionally, security requirements must be tacking into account. Overcoming such drawbacks with a proper design will provide the students with a preliminary deep experience on the power system behaviour.
A variety of instruments has been used in the past, at first electromechanical instruments and subsequently electronic ones.
The powerful improvement of the advanced technologies has considerably modified the teaching perspectives, as regards the didactic subjects and, more generally, the pedagogical point of view. The cultural background of the students is also changing, therefore the methodology as well as the didactic planning of the measurement environment need to be modified.
In the last years the authors developed some tools for experimental training of the undergraduates. In previous developments they proposed several educational systems, aimed to enhance the effectiveness of the experimental activity in the laboratory. In the progress of the work, advanced technologies have been used, among them virtual instruments, implemented in the LabVIEW™ environment, micro-controller, digital acquisition board installed in the PC, suitable software, super visioning tool and web cam.
Basic experimental sessions also include measurements on first-order and second-order systems. For this purpose a system has been developed which consists of a motherboard connected to two function generators and a digital oscilloscope; a dedicated software running on a personal computer controls the system [3].
This approach has provided quite good results, therefore a new hardware/software tool has been carried out and will be presented in the next future.
The possibility of remotely controlling connected instruments has been accurately analysed: this technique will represent a key point for future remote laboratory sessions. On account of such results, some approaches have been recently dedicated by the authors [4, 5, 6] to the three-phase system measurements and some hardware and software tools have been implemented.

Each tool has been designed in order to meet peculiar features and to exhibit didactic importance.
Two solutions to perform educational laboratory tasks in the field of three phase systems have been recently presented [7]:
1. The first tool implements a remotely managed laboratory session, which eliminates time losses needed for realizing the connections between the instruments and the other parts of the experimental set-up. A web connection improves the feeling of the students in performing true experiments.
2. The second system represents an evolution with respect to previous solutions: a stand alone laboratory session is implemented by using a micro-controller based architecture.
A key point of the adopted strategy consists of using smart and stand alone architectures, efficient paradigms for signal processing.
The extremely reduced cost of the solution proposed, compared to traditional set-up to perform the experiment, allows for an efficient duplication of the laboratory session, leading also to competition among student groups.
The core of the experiment is the management of user-friendly environment for signal processing and elaboration (hardware, firmware and software tools are used): it allows the student interacting with the whole system, producing his own modification and then validating the obtained results.
In this paper the two already presented tools are briefly reported, in order to emphasize their features, because they are didactically meaningful.
The second tool has been completely redesigned; the didactic importance and value of this work is indicated by the fact that a group of students in electrical engineering area has developed the tool in some guided sessions.

2 Tool for Remote Training

The didactic usefulness of a recently realized tool [6] can be emphasized with reference to the Fig.1, which represents the image on the monitor of the PC of a remote user.
The circuit diagram on top of the figure shows the traditional arrangement of the three-phase symmetrical system in case of balanced load. The first box includes the model of the load, which consists of three equal impedances in the star connection.
The two watt-meters in Aron configuration and the voltmeter represent the set of instruments needed for carrying out the measurements by using traditional electromechanical instruments. They are actually used in the lab: indeed, the figure under the circuit diagram is the image captured by the web-cam.

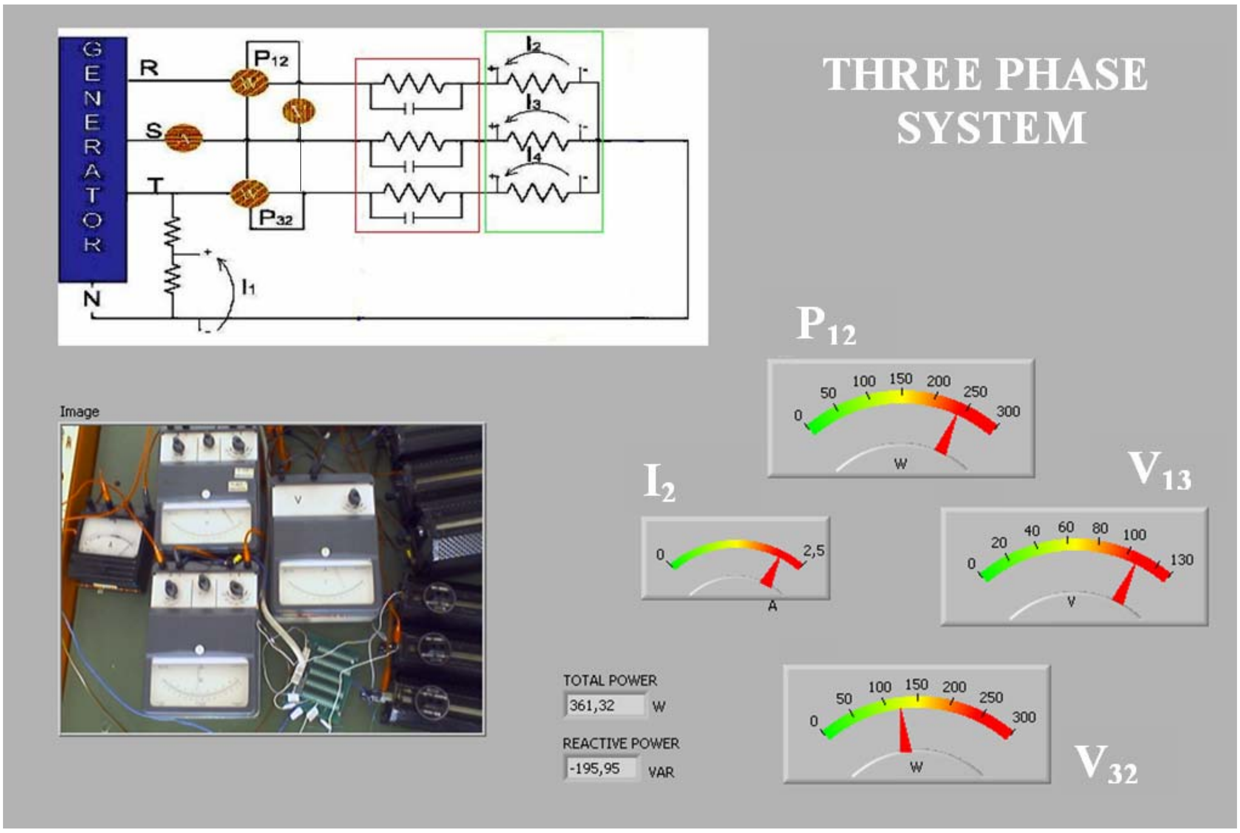

Fig.1: Virtual instrument on the remote monitor.

In order for the undergraduates to understand the use of some advanced technologies, a virtual instrument has been realized, implemented in LabVIEW™.
The realized software computes the voltages of the three-phase system on the basis of the voltage at the voltage divider.
The voltages at the terminals of the three resistors included in the last box of the circuit diagram are used for computing the line currents.
The software performs the various procedures for the realization of the virtual instrument and displays the results on the same figure. Indeed, the digital virtual instruments on the right appear to be a replica of the electromechanical instruments, so the remote user can compare the values displayed by the two sets of instruments.
The opportunity of comparing the characteristics of traditional instruments and the ones of advanced technologies is enabled by the web-cam, located in the lab: the image delivered to the remote user is shown on the left hand site of Fig.1.
Moreover, the software computes the values of both the total active power and the reactive power, displayed on the proper boxes.

2.1 Characteristics of the Tool

The tool exhibits some didactically useful features:

- electromechanical instruments are used;
- virtual instruments are implemented in the LabVIEW™ environment, which emphasizes the difference between the traditional apparatus and advanced technologies;
- additional electronics is needed, because it is quite difficult to adapt the level of signals supplied by the real three-phase system to the ones that can be applied at the inputs of the data acquisition board.
- this system can give to the undergraduates a good basic knowledge of the three-phase electric system.

It should be pointed out that the arrangement and the connections of the various pieces of hardware must be realized very carefully.

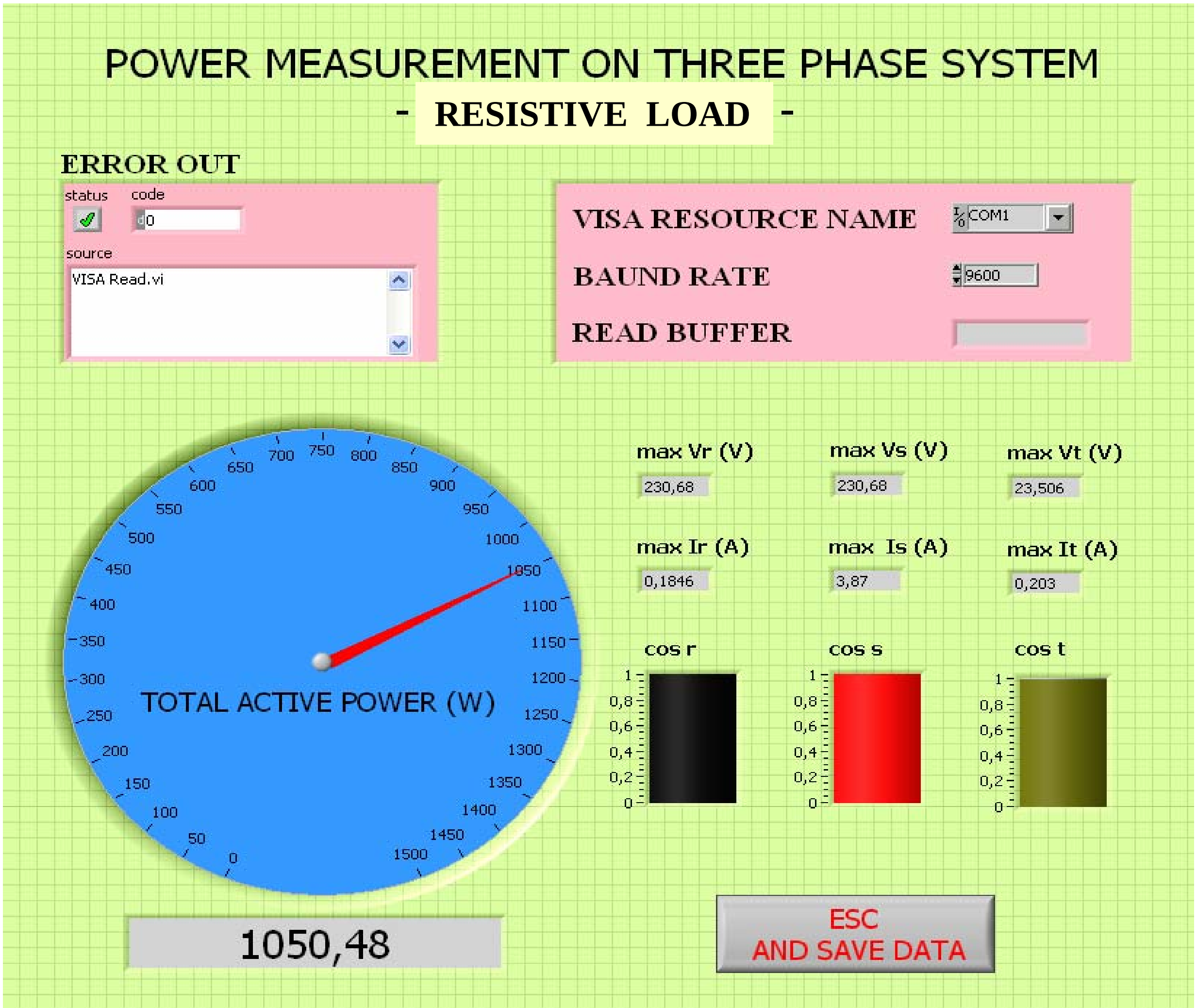

Fig. 2: User interface of the previous instrument.

For this reason, the system has been designed as an user friendly tool for remote users. Indeed, it can be left in the lab, with the PC connected to the network.

3 The electronic Power Meter

The last didactic tool already presented [7] was based on the micro-controller ST52F513 belonging to the ST-FIVE family of 8-bit Intelligent Controller Units (ICU), by ST-Microelectronics; it requires the Visual Five by ST-Microelectronics environment for programming. Data processed transferred to the PC were then managed by a dedicated environment developed in LabVIEW by National Instruments. Indeed, it allows for the development of software instruments dedicated to smart and efficient signal processing and data manipulation. It employs many facilities to manage general purpose and advanced hardware through communication supported by standard protocols. In the considered case an RS-232 connection between the microcontroller board and the PC was established. The user interface of that virtual instrument is shown in Fig. 2.

The didactic value is quite evident. This instrument has been completely redesigned, in order to present some peculiar characteristics and can be used as a portable electronic active and reactive power meter, in a wide current range (220 V, 0-20 A).

The hardware consists of some boards, designed for reducing the input voltage and current values, for adapting and conditioning the signals, for decoupling the impedance in order to realize the correct connection to the microcontroller, for programming the micro-controller, and the last one for managing the communication with the computer. The adopted micro-controller is the PIC18F2620. The software for programming the PIC18 is MPLAB IDE v7.40.

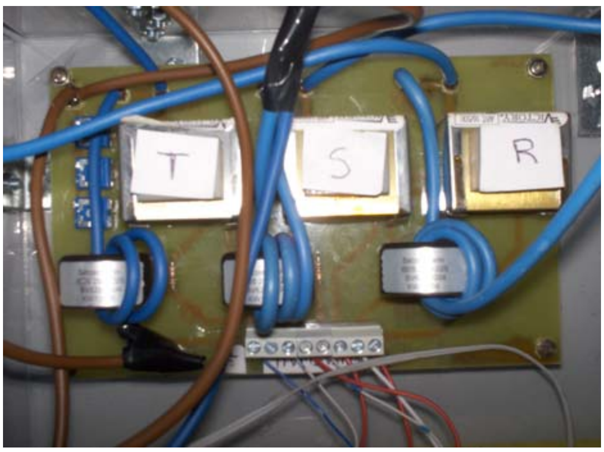

Fig. 3: The signal conditioning board.

3.1 Signal conditioning

As shown in Fig.3, three transformers are used in order to suitably reduce each phase voltage. This choice depends on the reduced dimensions of these devices. Consequently, the load on the secondary coil is kept very low in order to minimize errors.

Three ammeter transformers are used for conditioning the currents. For each bus a buffer is used for impedance decoupling, therefore the impedance connected to each transformer is very high. In order to overcome some constraints for the signal to deliver at the inputs of the micro-controller, a configuration based on operational amplifier has been designed for each bus (Fig. 4).

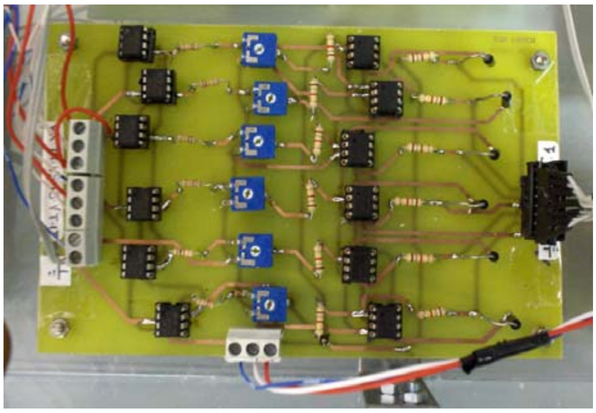

Fig. 4: Impedance matching and signal conditioning.

3.2 Signal processing

When the values of the voltage and the current for each phase have been acquired by the micro, the apparent power, the real power and the reactive power will be computed. Under the hypothesis of sinusoidal voltage and currents, the following relation has been used for computing the power factor:

$$\cos\varphi = \frac{(v \cdot i)_{MAX}}{V_{MAX} \cdot I_{MAX}} \cdot 2 - 1 \quad (1)$$

therefore the real power can be obtained:

$$P = \frac{1}{2} V_{MAX} \cdot I_{MAX} \cdot \cos\varphi \quad (2)$$

and consequently the other quantities.

The formula (1), under the assumed constraints, overcomes the problem of using trigger threshold for start-stop signal generation, as it is needed for a direct measurement of the phase shift. Moreover, no real-time sampling is needed in this case.

A common communication program, the “Hyper Terminal”, has been chosen for displaying the results. Fig. 5 shows a summary of the hardware, the micro-computer, its programming environment and the presentation of the results.

4 Conclusion

Two developed didactic tools have been presented:

- The first one fulfils some requirements: it includes electromechanical instruments for a very clear understanding of the system operation, is based on a virtual instrument and will be used in distance learning sessions.
- The last tool implements an electronic active and reactive power meter, based on a micro-controller and a virtual instrument. At present it is used for training of undergraduates. Future development will be the characterization of the instrument.

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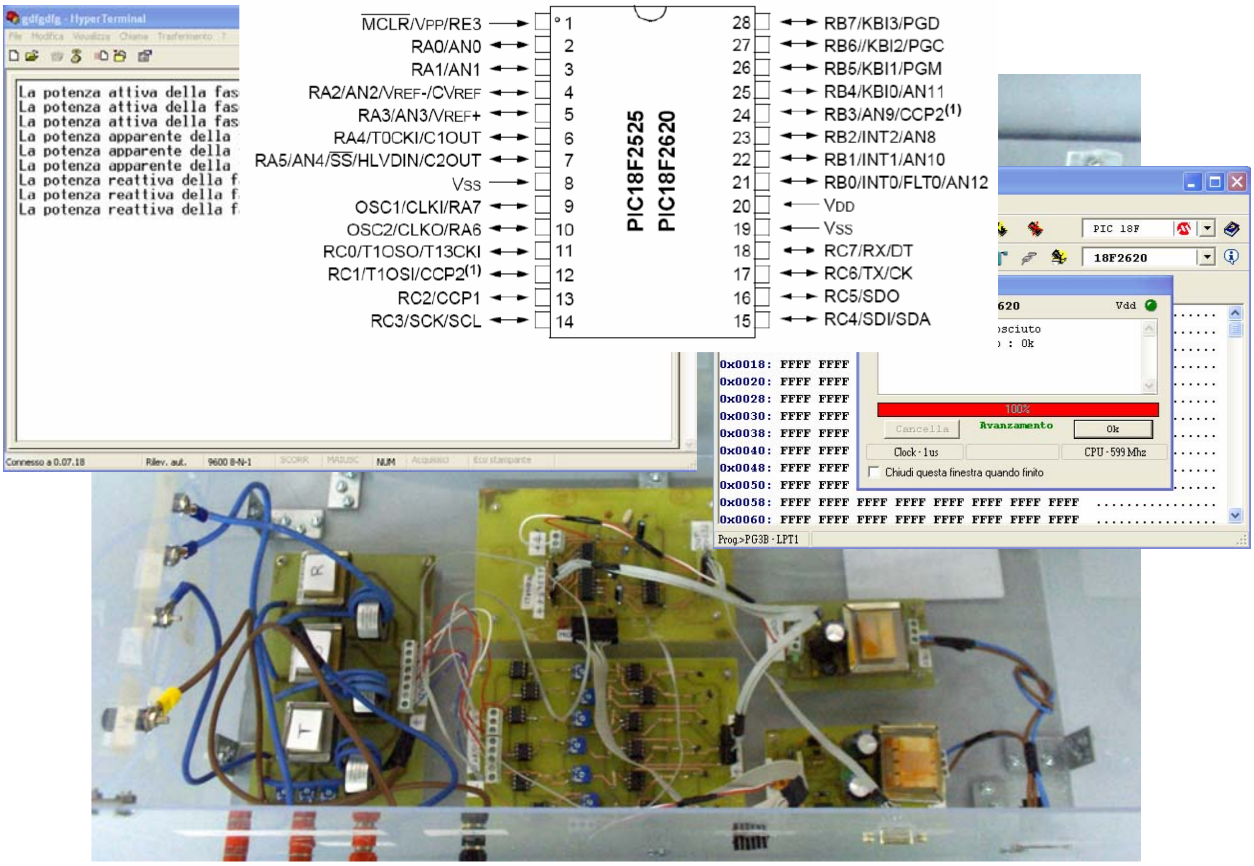

Fig: 5: The overall system.