Measuring the Quality Indicators of the Electric Energy Service

Robín A. Peña, Víctor A. Gómez, Cesar Hernández

***Abstract*—This article presents the design and construction of a prototype to measure the quality indicators of the electric energy service, which has capacity to measure the discontinuity in the service based on a voltage presence sensor that generates logic states in its exit, so the algorithm designed in a high level C and implemented in the microcontroller PIC18F2550, can register the events occurred in a period of three months. The prototype is built mainly by a liquid crystal display, a microcontroller, an external memory and a real time clock. This measuring device has a low functional cost, high memory to register the events and a high precision level in measuring the duration of interruptions.**

***Index Terms*—DES, FES, service quality, sensor, microcontroller, memory, real time watch**

I. INTRODUCTION

TODAY with the advance in technology, as mentioned in [1] [2], most of the electric and electronic equipments of domestic and industrial use are more vulnerable to variations in the fundamental working. Therefore, the continuity in the electric energy service is important. On the other hand, the user is made firm to the indicators informed by the company through the invoice, and in consequence to the economic compensation that is calculated based on these indicators. [3], and does not know with certainty if in any trimester, the quality of service has been paid to be inferior according to the established stuff by the regulations of the Gas and Energy Regulations Commission (CREG).

In consequence, there is not in the market a measuring device that has the necessary characteristics for the trimester registry of the quality indicators that provide support to the residential costumer to demand his compensation when the maximum values have been surpassed.

On the other hand, the existing measuring devices [4] have a high cost, which makes them inaccessible for the residential user.

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The development of the project begins with the selection of the technology to be implemented and the acquisition of the required knowledge. It is selected a high level microcontroller with microchip (PIC18F2550), due to its versatility, high processing level, memory capacity, analog-digital ports, Universal Serial Bus Communication (USB), good availability in the market and low cost. [5].

Also, for the design of the algorithm, a compiler CCS C (PIC C Compiler) was used for its easiness in relationship with the tools for the interfaces with external devices as a real time clock (DS1302), a crystal liquid display (LCD) and an external memory EEPROM (Electrically-Erasable Programmable Read-Only Memory) [6].

Then, the voltage sensor was designed based on the theory of the semiconductor devices. At the end the autonomous feeding of the prototype was designed. In fig. 1 a block diagram of the prototype design is illustrated where modules can been checked.

According to the study of parameters, and the requirements of the measuring device, it has to measure the entry variable (network voltage) by a voltage sensor and based on the lecture of it, store in a memory the interruptions in the continuity of the electric energy service, taking in consideration the hour and date of the events done to show them in an LCD screen.

II. ARCHITECTURE OF THE PROTOTYPE

To be able to comply with the requirements of the prototype, the following devices are used in its implementations:

A. *Monitor Module*

They are built mainly of: diodes as restrainers and rectifiers, BJT transistors working in cut state and saturation and condensators as filters.

B. *Processing and register module*

It is composed by three devices:

- Microcontroller PIC18F2550, that has analog-to-digital converter (ADC) module that allows us to read the state of the batteries and communication protocols THREE WIRE and I2C for the bi-directioning of data between the PIC external memory and the real time clock.

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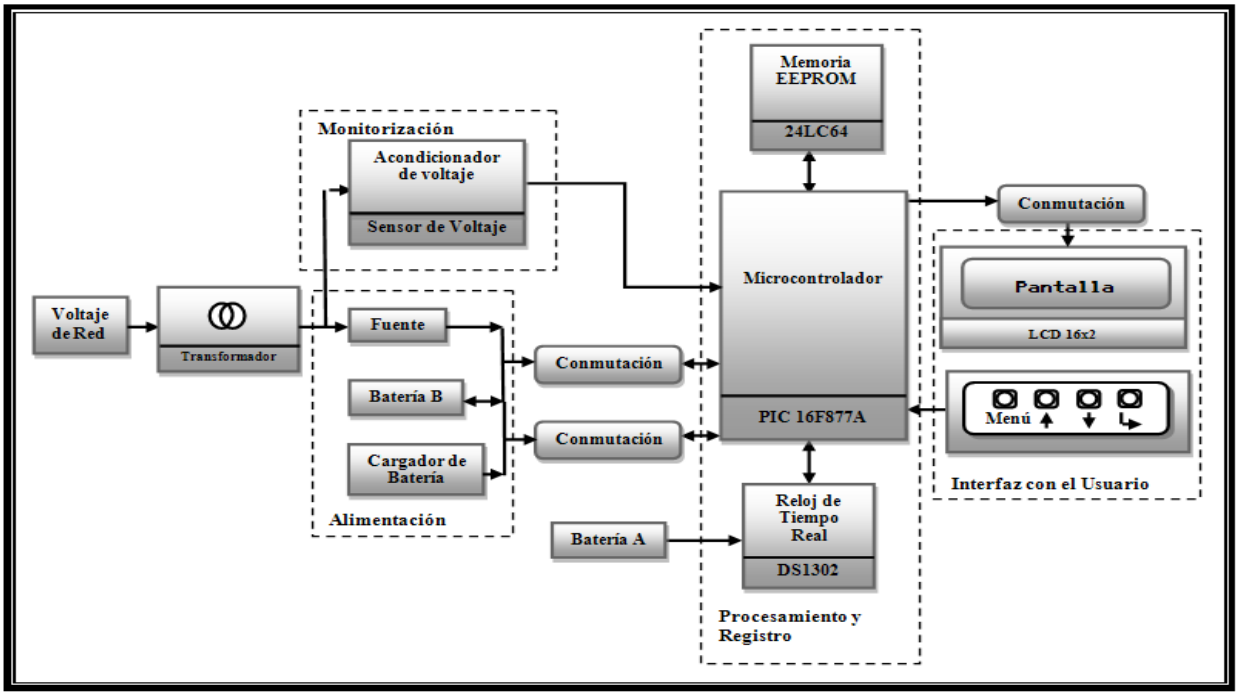

Fig. 1. Block and module diagram of the composition of the measuring prototype.

- Also it counts on a memory program of 32 Kbytes that is occupied in 50% by the designed algorithm.
- External memory 24LC64 with a capacity of de 64 Kbytes, that allows us to store approximately 904 interruptions in total or 226 interruptions each trimester.
- Real time clock DS1302, that uses a 32.768 KHz crystal and its communication is synchronic series type. This device counts seconds, minutes, hours, days, months and years, taking in consideration even leap years.

C. Interface with the user module

It is composed by a Hitachi Hd44780u (Lcd-Ii) LCD screen of 16x2. Also it counts on four pulsators with the following functions: Menu, Enter, up and down.

D. Feeding module

This module, as observed in Fig. 1, is made of:

- Source A (main), is made of a transformer of 120/12 VAC of 200mA, a DF08M rectifier of 1A, a filtering stage of 2200uF and a LM7805 regulator of 1A.
- An A battery, that is a voltage cell of 3V.
- A B battery that is an AGM battery (immobilized electrolyte) MT1208 of 12v with a capacity of 0.8A/H.

For the protection of the prototype a varistor against over tensions and a fuse of 100mA amperes against over currents were used.
At last, the design of the printed circuit (PCB) was made using the software EAGLE 4.16 and ALTIUM DESIGNER SUMMER 08.

III. DESIGN AND IMPLEMENTATION OF THE PROTOTYPE

The Following modules are exposed to constitute the prototype for measurement illustrated in Fig. 1.

A. Monitoring

A sensor of voltage presence was designed to generate logic states in its exit related to the network voltage of the entry, as illustrated in the block diagram in Fig. 2, based on two essential requirements: short time of answer in the exit upon a change in the entry and low consumption of energy in the voltage sensor.

The voltage sensor is fed by a DC source of 5V that is in charge of generating the logic states in the exits of it and an AC source coming from the RED signal of the secondary of the transformer.

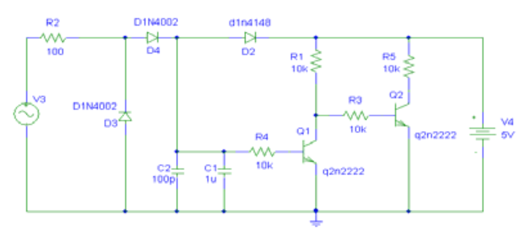

Fig. 2. Voltage sensor circuit

The sensor shown in Fig. 3, is made mainly by: a fastener to lift the AC signal, a rectification stage and a filtering stage to decrease the curls of it [10]. These stages allow to generate a continuous voltage that maintains constantly in saturation a transistor. When the interruption of the service occurs (AC entry voltage of the sensor equal to 0V), the transistor passes from saturation to one cut state, allowing commutation of the 5VDC to 0VDC, the microcontroller takes as logic states of the variable being studied.

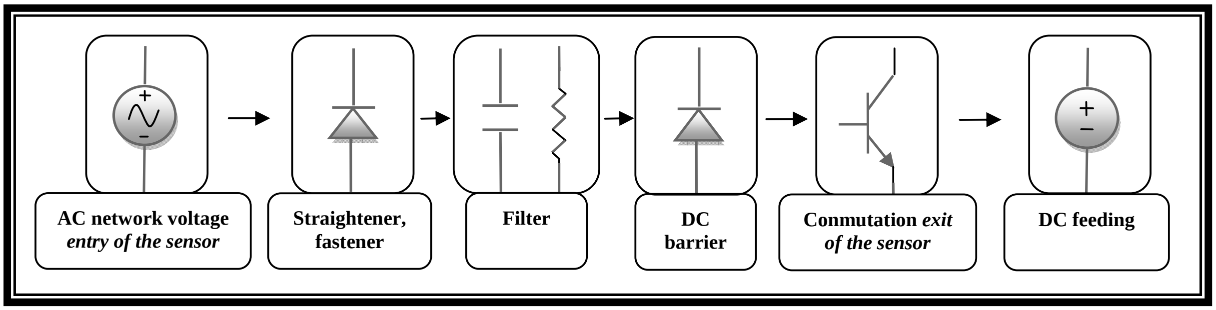

Fig. 3. Block Diagram of the voltage sensor

B. Processing and registry

In Fig. 4 the schematics of the processing and registry module are shown. In this module, the algorithm implemented is found in C language that allows:

- Register the DES and FES count of the trimester.
- Time the interruptions in the continuity of the service delivered.
- Store each event in an external memory with the following data: duration of the interruption with: hours, minutes, seconds and date of the interruption with: hour, minute, day, month, year and trimester.
- Organize the interruptions in trimester folders where can be visualized the DES and FES of each trimester during a year, as the registries of each interruption.
- Perform three commutations: the entry of the batteries as energy source when an interruption is presented, the charge of the batteries when it is detected that they have no charge and the on and off of the screen to minimize the consumption of the prototype.

This algorithm is also in capacity to: restart the DES and FES of the trimester when it changes, restart the external memory when the capacity of it is full, register an interruption only when the duration of it is above one minute and enter the energy saving mode when the user has not manipulated the prototype in one minute or when it is in the middle of an interruption. In Annex A, the flow diagram of the designed algorithm is illustrated.

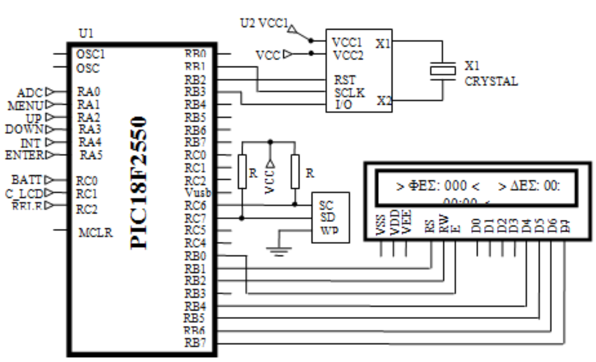

Fig. 4. Processing and registry

C. Interface with the user

The interface with the user is composed of an LCD screen and four buttons that allow it:

✓ Observe in the screen a main box where the current hour and date can be verified,
✓ The chronometer of the interruptions,
✓ The DES and FES of the trimester in course
✓ An interruption menu where can be found the event registry divided in folders for each trimester.

The four buttons allow the user to enter the interruptions menu and go through it. In the manual is found some detail descriptions of the user interface are found.

D. Feeding

This feeding module is made of three energy suppliers:

Source A: It is fed by the electric network; it transforms, rectifies, filters and regulates the entry voltage to the prototype and is in charge of supplying the electric energy to it as long as there are no interruptions in the service.
Battery A: It is a 3V clock battery. This is used due to the fact that the real time clock makes an account the RAM registry times (random Access Memory), and has to be energized permanently so it does not deconfigurate.
Battery B: It is a highly autonomous battery (0.8A/h) to feed it in the same moment of the interruption.

Given the demand of energy supplied by battery B and the consequent discharge of it, it has to be recharged through a charger. The prototype measures every thirty minutes the charge volume of this battery through a resistive divisor and an analog-digital port. Based on this measure it determines if it commutes or not the battery charger.
The design of the charging circuit of battery B was made based on voltage graphics, charge volume, current and number of charge cycles specified in the technical sheet of it.

IV. TESTS AND RESULTS

They were made the following working tests to the prototype in the electric machinery laboratory of the Distrital University Francisco José de Caldas:

A. Response velocity test of the voltage sensor

An instantaneous interruption of the service was emulated and the tension was measured on the electric

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network, regarding to the exit signal of the voltage sensor. This way the tension signals were obtained. They are shown in Fig. 5.

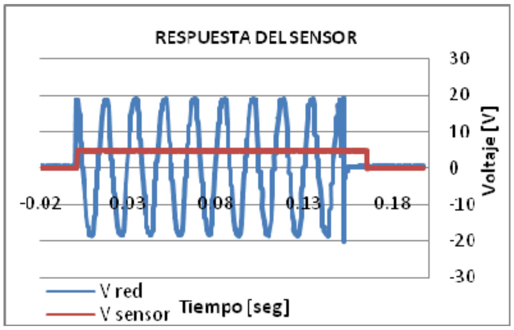

Fig.5. Answer velocity of the voltage sensor

As it can be observed in Fig. 5, the answer of the sensor upon the reestablishment of the energy is almost immediate (1.6 ms), as that at the moment of occurrence of an interruption the answer of the sensor is late (12 ms): this way the relative error of the measure of time is:

$$\delta_R = \frac{(Tm) - (Tm - Trd)}{Tm} * 100\% \quad (1)$$

Where:

- *Tm*: it is the time to measure, 60s
- *Trd*: it delays time for the detection of the interruption in the service, equal to (12 ms – 1.6 ms). It is given that the time in the detection of the beginning of the interruption compensates the time in the detection of the final of the interruption.

$$\delta_R = \frac{(60) \quad (60 \quad 0.0104)}{60} * 100\% = 0.017\%$$

With this fulfilled, the requirement of the sensor in terms of answer velocity from an interruption in the energy service, due to the fact that the calculated relative error is not significant. In consequence, the precision of the error measurement of Tm is in the order of thousands of a second.

B. FES test

A circuit using a bi-stable electronic timer was designed, a tiristor and a Opto- joint, to emulate multiple interruptions in the continuity of the service. It was configured in such way that one and a half interruptions were generated every two minutes. This way was found that the maximum number of interruptions that the prototype can register in one trimester is 226.
Consequently the maximum number of interruptions that the prototype can register in one year is 904. The prototype can register a maximum of four trimesters.

C. DES test

The maximum time of an interruption that can register the prototype is in function of the autonomy of battery B. a test emulating a temporary interruption was made and the maximum approximate time was found having a value of 72 hours (3 days).

D. Potency consumption test

For this test, the instantaneous potency measuring, the current signals and the voltage in the entry of the network to the prototype to find the active current were registered. The results can be seen in Fig. 6. By numeric integration, the active potency value consumed by the prototype equal to 740Mw can be found.

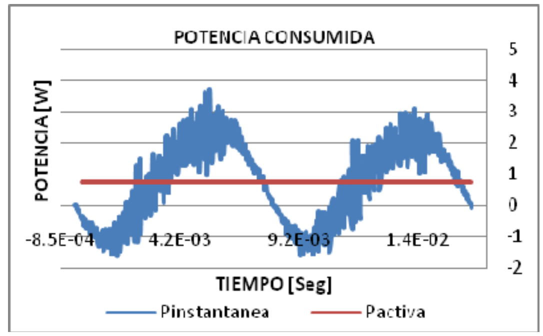

Fig.6. Instantaneous potency and active potency

E. Over tension and over current test

Supplying a voltage over the nominal in the entry of the prototype and simulating a short circuit over it, the correct dimensioning of the measurer protections were verified.

V. COSTS

The associated costs of the measuring prototype of the service quality indicators were mentioned.

A. Working costs

Given the potency consumed by the prototype and the price per KWh for the residential user in strata 1 ($310, 5088) it is considered that the price of energy consumption is of $165,00 per month or $1.982,00 per year. It has to be taken into account that this consumption was calculated when the prototype was demanding its maximum energy.

VI. TECHNICAL SPECIFICATIONS AND PROTOTYPE INSTALLATION

The device has to be connected to bifilar monophasic system. The following conditions for the measurer are stated:

A. Electric characteristics of the measurer

- Nominal tension (Netral Face): 120 VRMS
- Line frequency: 60 Hz.
- Maximum tension: 180 VrmsVRMS.
- Connection: Bifilar monofasic

B. Prototype installation

The measuring prototype has to be installed between the energy measurer and the distribution board, due to the

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fact that it cannot be located in the source because the operator of the network does not allow connections before this point [11], it cannot be located either after the totalizer of the distribution board, given the fact that a failure in the residential electric installation that ignites the termomagnetic interrupter cannot be taken as an interruption in the electric energy service. In the user manual is specified the connection to the prototype.

VII. RECOMMENDATIONS AND FUTURE WORKS

As an aggregated function, it would be convenient that the prototype could measure the quality of the potency.

VIII. OBJECTIVES REACHED AND NOT PROPOSED

A user interface through a Universal Serial Bus Communication Device Class (USB CDC) was developed. This type of communication emulates a Recommended Standard 232 (RS-232) serial port for the exchange of data between the measuring prototype and the PC. This type of communication uses the drivers supplied by Windows, which are Usbser.sys and the Ccport.sys, in the same way Microchip supplies the Mchpcdc.inf file for the identification of the prototype and the optimization of the communication.
After obtaining communication with the PC, it is necessary to have a platform for the reception of the information censed by the measure, therefore, a software with the help of Microsoft Visual C# 2008 Express Edition that establishes a bidirectional communication of data between the PC and the DES and Fes measurer was developed.

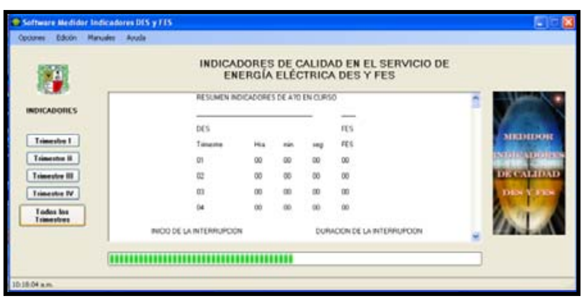

Fig.7. Software of quality indicators

This way, the user will be in capacity to observe in the computer the service quality indicators and the same way can have a written support for the claims in case that the maximum values of them are surpassed.

IX. CONCLUSIONS

This Project has fulfilled its main objective, which has designed and built a prototype to measure the quality indicators in the quality of the service for electric energy (DES and FES) for residential users.
It was obtained a high answer speed in the voltage sensor designed. In consequence, the error in the measurement of the duration of the interruptions is not significative, and thus the probability that an interruption with a duration under one minute being registered in minimum.
Taking as reference point the maximum amount of interruptions allowed by CREG for the year 2009 [12] (58 interruptions group 4), and given that the prototype is in capacity to register a maximum of 904 interruptions in a year, we noted that the memory of the device registers up to 15 times the maximum number of interruptions allowed in a year. Also, the autonomy of the prototype is enough to register a temporary interruption up to 3 days.
Due that the prototype will consume energy without interruption; the cost of functioning for it has to be low. Therefore, the operation cost for one year is $1982.00 was achieved for a residential user in strata 1 subscribed at a cost for KWh of KWh $310,5088.

By the software designed “DES and FES indicator software measurer” and the USB communication, the user is in capacity to keep the registries of the interruptions in physical and also magnetic.

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