Power Quality Monitoring System With Distributed Metering Points

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Abstract - **Nowadays, the control over every minimal cost is being very important for the market competition. Since the electric energy bills represent a great amout of exepenses for the companies, the monitoring of the power quality helps to lower the energy costs and to prolong the machine's lifes. But, not every company can pay for an expensive resource that helps to minimaze the expenses. This paper presents studies and development of a low cost electrical energy monitoring system, that consists of a digital energy meter, a software for the system management, a database to store the measurements and a WebPage to monitor the energy quality from anywhere, through the internet. Algorithms of calculus are proposed for implementation. Physical environment and communication protocol are also proposed. Programming languages are studied and used to develop the software and database.**

Keywords – DataBase, Monitoring, Power Quality, Software Analyzer, Waveforms.

I. INTRODUCTION

A power quality problem is an occurrence manifested in a nonstandard voltage, current or frequency deviation that results in a failure or misoperation of end-use equipament. New electronic devices are more susceptible for low power quality events, like sags, swells, transients, flickers and harmonics distortion. These PQ problems can impact in operation costs by downtimes and lost productions [1].

The challenge of any industry that depends on electrical energy for production is to lower the consumption, with high power quality, increasing profit. Electrical energy managers were created attenpting to maximize the electrical energy utilization and help fault detection. The market competition has forced electrical energy consumer of the industrial sector to take the necessary steps to minimize costs, maximize power quality and ensure the correct operation of the manufacturing process. Monitoring systems that helps to obtain information of the electrical parameter on the plant, can be used to achive these goals. Researches shows that Power Quality is a serious and relevant subject in respect of operational costs, and also shows that about million dollars are lose every year in the industries by the bad use of energy [2].

An electrical energy monitoring system is proposed in this paper. The hardware is based on a ARM_7TDMI Core 32 bit RISC microcontroller, which has serial communication through RS-232/485 network and uses the open protocol Modbus RTU to communicate with the software.

The system can present waveforms and calculate PQ parameters, as well as store and read information from the database, that can be accessed by a webpage with HTTP protocol. The low costs are maintained using free softwares, like "PostgresSQL" and "Apache WEB Server", and cheap eletronic devices.

The monitoring system can be classified as a 2nd generation PQ device, but with functions of a 3rd generation. The system can be classified between an Analyzer and a Monitor System [1].

At the industrial plant is very important to be possible to make a feedback of the PQ parameters and the machines eletrical conditions on the meter. That's why the hardware proposed in this article has a display to show the informations, diferently of [1]. This is possible using a microcontroler with a high operation frequency, costing a litle bit more then a comon one.

II. MONITORING SYSTEMS

A complete monitoring systems is basically composed by four components: Meters, a management Software, a Database and a WebPage. When these components are working together, it represents a powerful system to find and evaluate PQ problems, diagnose, and improve the energy.

A. Metering Instruments

Many commercial meters, analyzers and monitors are in the market. These devices have different functions and prices. But almost all of them are expensive, and many companies can´t pay for it.

The meters have functions like Voltage (V), Current (I) and Power (P) measurements. Analyzers can measure V, I, P, Harmonics, Waveform and Events. Monitors have continuous and proactive objectives, having analyzers functions, statistics and indices contents[1].

B. Analyzing and Monitoring Systems

Instruments to measure and control PQ parameters ordinarily have systems to analyze or monitor PQ events. The use of closed communication protocols by these systens make very hard the integration between equipments of different manufactures.

Systems can use wavelet transform, artificial networks or different kinds of intelligence to classify PQ problems [3-6].

III. Proposed and Implemented System

The monitoring system can have the maximum of 32 PQ meters, because of the RS-485 network. The communication protocol used is Modbus/RTU, because that is very robust and trusty, and exists a lot of commercial meters using this protocol, because it allows a migration to the Ethernet enviroment (TCP/IP). Figure 1 shows the topology proposed.

The proposed system offers flexibility on the data to be obteined by the software. When a meter is registered at the software list, it sends the configuration message to the meter, that responds if everthing is right, or if there was any problem.

The principal parameters to be set are the net address of the meter, the fases (TA,TB,TC,CA,CB,CC) and the number of cicles (from 1 to 16) that the AD should capture, and the number of points per cicle (from 32 to 256). It´s done for the memory otimization, because the user could want to monitor only the voltages (TA,TB and TC), or the currentes, or the voltage and current of the fase b, for exemple, with more cicles and less points per cicle, the length of the vector can be dimentioned according to the necessity, as well as at the software as at the hardware.

This flexibility in choosing the number of cicles and points per ciclo is also to permit the acquisition of more then one cicles without overloading the serial line.

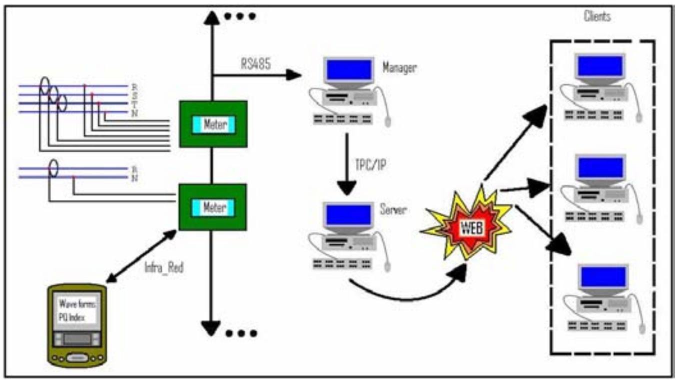

Fig. 1. System Topology

A. Implemented Functions

All algorithms implemented in the PQ device were first developed in the simulation environment MatLab/Simulink. By using this software, more accuracy and condensed algorithms were reached.

The PQ device realizes calculus of energy quality factors looking for ally low cost with the greater number of performance functions. Using platform with microcontroller and C programming language, this prototype performs calculus of RMS values, total harmonic distortion (THD), power factor (PF), the displacement factor (DF) and powers. These are local functions (at the display screen), described in TABLE 1.

These calculus were based on simple algorithms with easy processing. These were performed using a well known conventional technique to compute the electrical quantities based on the Discrete Fourier Transform (DFT).

New methods to give the magnitude and phase of voltage and current measured, more quickly and accurate, called the new least squares algorithm [7], are been studied to future implementation.

B. PQ Intelligent Electronic Device

A prototype of PQ IED was developed with low cost components. The electronic board consists of the supply, micro-controler, communication, signal conditioning and flash memory modules. The functionality can be described in Figure 2.

The PQ IED can be configured localy, through the buttons, or remotly, by the software, with the parameters explained above. After the configuration, it´s ready to aquire the voltage and current information, store in vectors and export to the software when it asks, trough the RS-485 network. Other ways to integrate the systems are in study, like cell phones, pocket PC, palms, wireless communications, Bluetooth and Infra-Red.

The possibility of having an USB port to store the data in a mass memory (pendrive) is being estudied for future implementation, as well as the comunication over Ethernet.

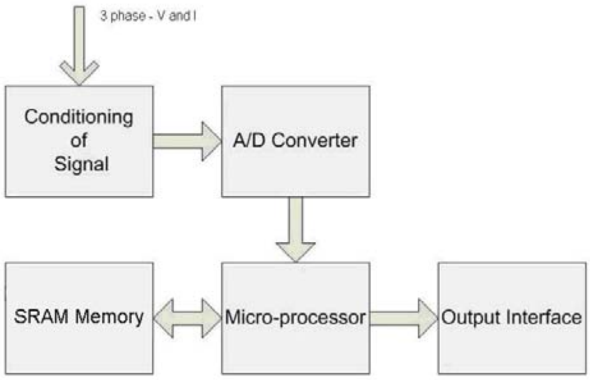

Fig. 2. Hardware Architeture

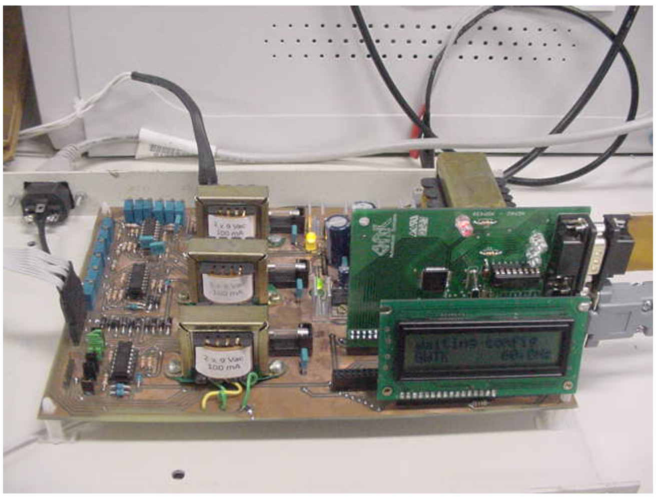

Fig. 3. Hardware platform developed.

TABLE 1
Basic Calculation Formulas

Vrms	$Vrms = \sqrt{\left(\frac{1}{T}\right) \cdot \sum_{n=0}^{j} ((V(n)^2 + V(n+1)^2) \cdot (pc)}$	Active Power	$P = \frac{1}{T}\int_0^T V(t) \cdot I(t) \cdot dt$
Irms	$Irms = \sqrt{\left(\frac{1}{T}\right) \cdot \sum_{n=0}^{j} ((I(n)^2 + I(n+1)^2) \cdot (pc)}$	Reative Power	$Q = \sqrt{S^2 - P^2}$
Form Factor	$Ff = \dfrac{Vrms}{\frac{2}{T} \cdot \int_0^{\frac{T}{2}} V(t) \cdot dt}$	Apparent Power	$S = VI$
Crest Factor	$Fc = \dfrac{Vp}{Vrms}$	Power Factor	$FP = \dfrac{P}{S}$
THDv	$THDv\% = \dfrac{Vrms(hamonic)}{Vrms(fundamental)}$	THDi	$THDi\% = \dfrac{\sqrt{Irms^2 - Irmsfund^2}}{Irmsfund}$
Harmonic Amplitude	$H = \sqrt{\sum_{i=1}^{f} \begin{matrix} (((V(i)2f\sin(2\pi fnt(i)) + (V(i+1)2f\sin(2\pi fnt(i+1)) \cdot (PC))^2 + \\ V(i)2f\cos(2\pi fnt(i)) + (V(i+1)2f\cos(2\pi fnt(i+1)))/2) \cdot (PC))^2 \end{matrix}}$		

C. PQ Software Analyzer

The software was developed with a powerful programming language, which allows, in an easy way, to use the Modbus protocol to get data from any meter at the net, treat it and give graphs and calculus results of electric measurements. Other positive points are the tools to connect the "manager" to the database, and write on it.

All the programming was done based on oriented object language, that makes the software flexible, and alows reutilization and changes in an easy way.

The functionality is basicaly: first the user should configure the comunication with the database (setting the company and the password) and the comunication over the serial line. After it, the meters can be cadastered, one by one, setting the parameters, and soon the meter is registered, the software sends the configuration message, and waits for the response. If it is received, the meter is inserted in the list, and a window is create for it. If the reponse arrives with problems, or isn' t received, the software will alert.

The parameters set for each meter are the number of cicles and points per cicle, the address, the timer, the fases and options of how to see and store the data, been it "plot the waves", "calculate the performance parameters" and "store the data at the database".

After all meters cadastered, the user can choose witch ones the software should ask for data and start the process, counting for each meter the timer. When the timer overflows, the software asks the data for the meter. The Figure 4 shows the software´s interface.

Since the Modbus PDU don´t permit frames bigger than 253 bytes, if a meter cadastered is programed to get information of TA,TB and TC, with 2 cicles and 128 point per ciclo, for exemple, the number of bytes would exceed the max number of data bytes of one Modbus transaction (each point is a "word" – 2 bytes). The number of bytes for this exemple would be:

$$3 * 2 * 128 * 2 = 1536 \text{ bytes}$$

Because of it, the software must do many requests, and wait for many responses.

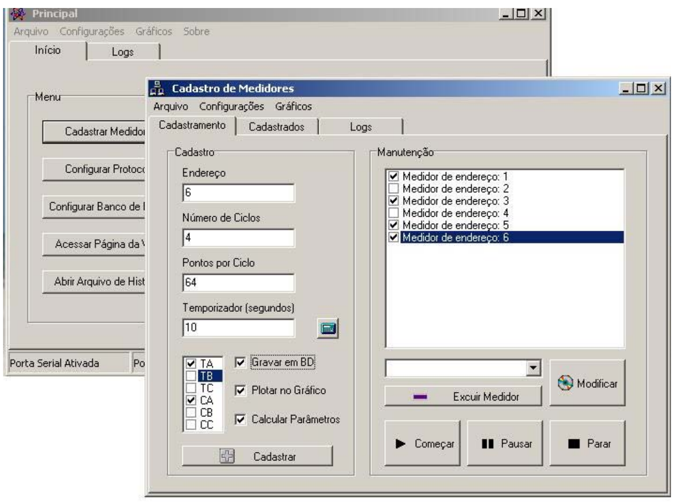

Fig. 4. Layout of the cadaster window

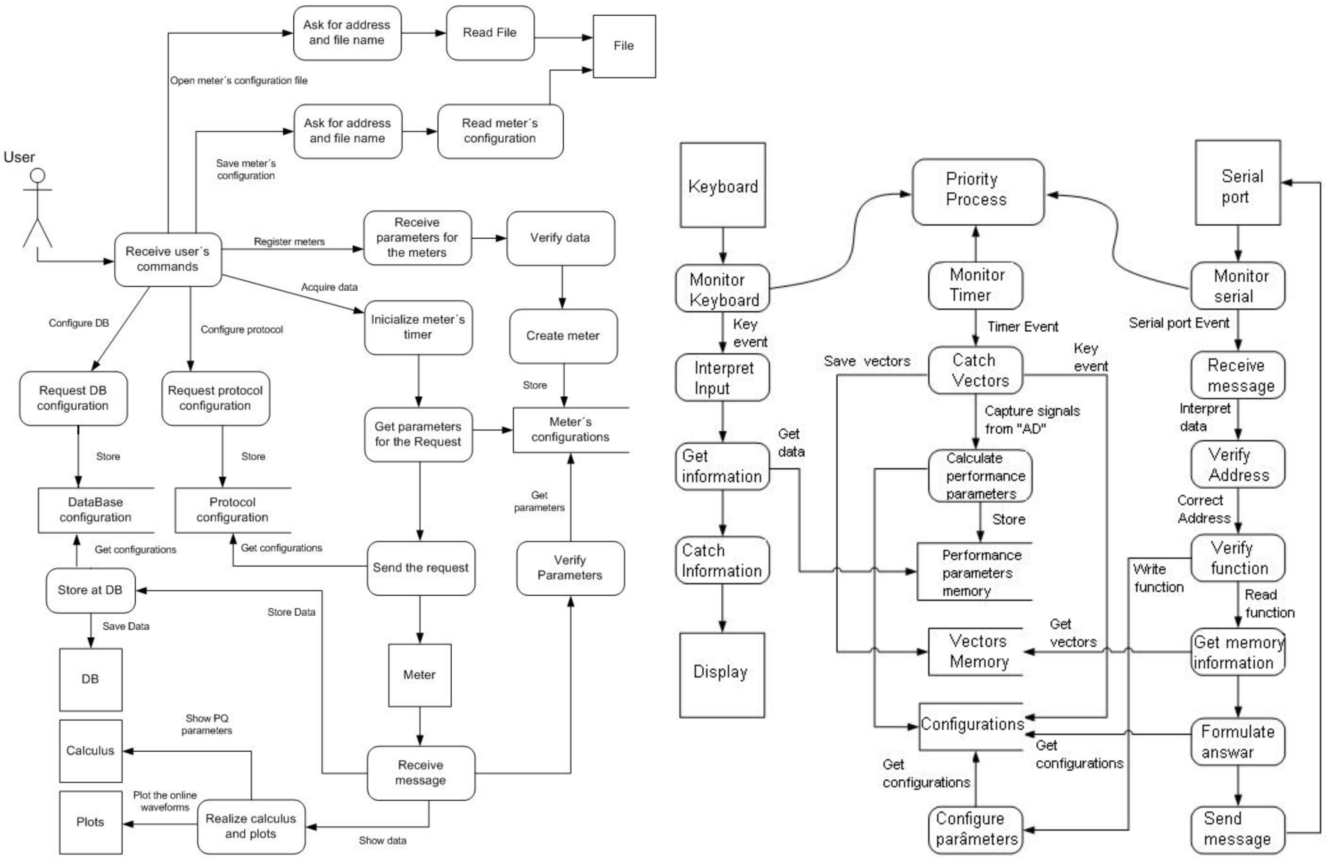

Fig. 5. Software and Hardware data flux diagram.

The Figure 6 shows the meter's windows, showing the online waveforms, the THD up to 12° harmonic, and the power quality parameters calculated for each fase (RMS voltage and current, total harmonic distortion, active, reactive and aparent powers, displacement and power factors and voltage imbalance).

Figure 7 shows anothers meters windows, hiding the PQ parameters and the THD plot.

The multi-window's way to visualize the online wavefons allows the user to trace a PQ disturb.

D. DataBase and WebPage

Database is important to the PQ system because it concentrates data for further analysis. This database stores the information in a single place. By this fact, the meters can have low mass memory.

Benefits using a database starts with reduced price of the meters, that allows it to be pulverized in an industry. Other benefit is the possibility to remote access of this data, through internet. This means that managers of industrial manufactures can have easy and inexpensive access to all the operational and economical data they need to do their jobs better and at lower cost [2]. Many other benefits are shown in [9]. The Figures 9 to 12 shows the webpage developed.

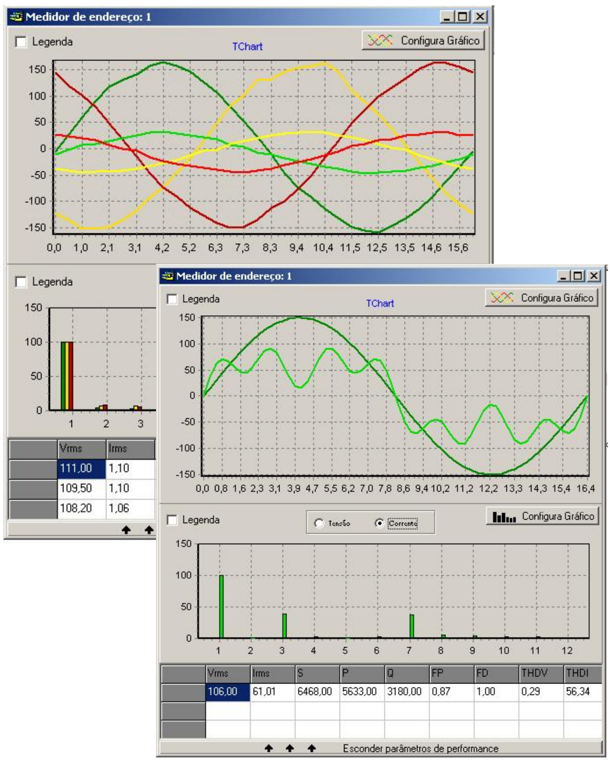

Fig. 6. Online plots and calculus

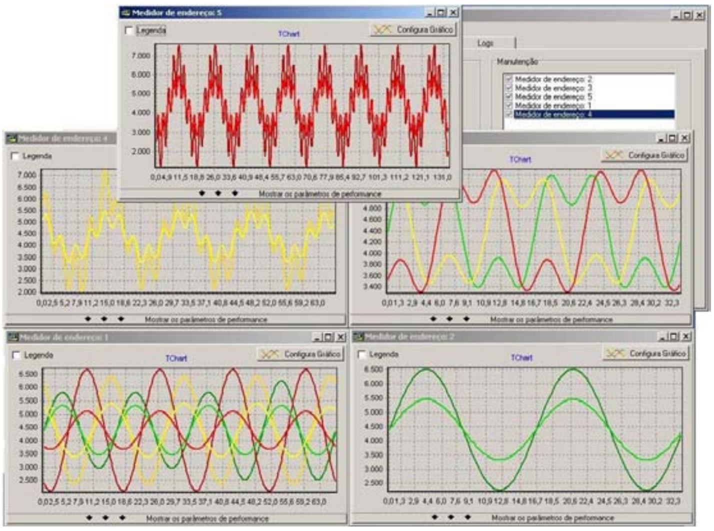

Fig. 7. Online plots

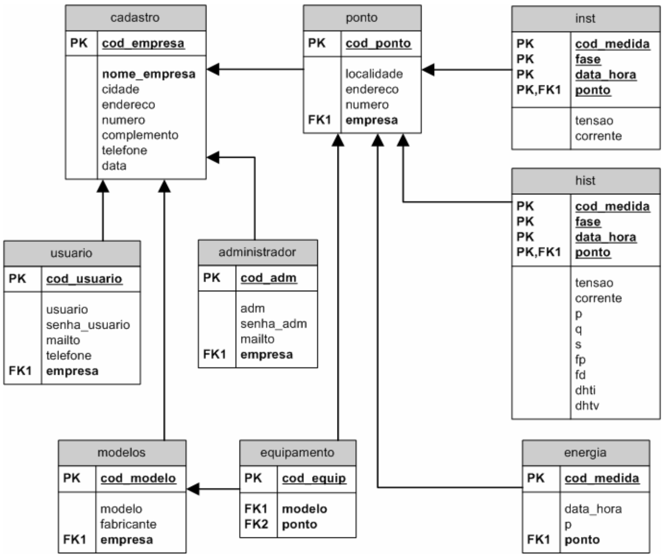

Fig. 8 – Relational entity diagram of the DB.

Fig. 9 – Choosing a cadastered company

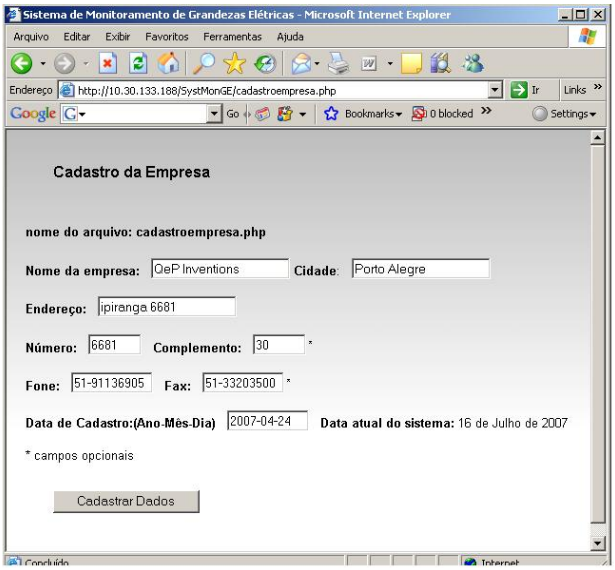

Fig. 10 – Registering a company at the DataBase

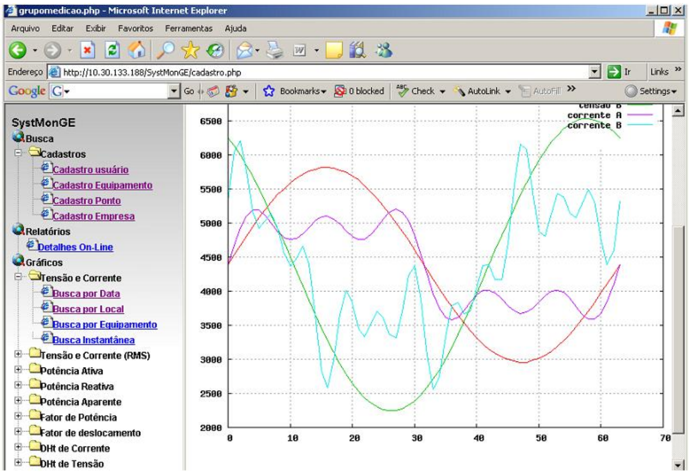

Fig. 11 – Research of instantaneous data.

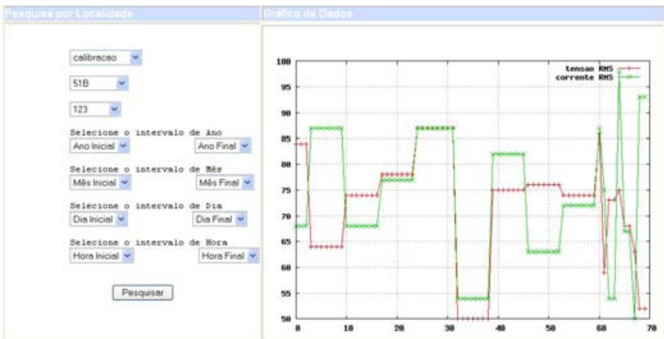

Fig. 12 – Research of historical data.

IV. CONCLUSION

This paper presented the development of an electrical energy monitoring system, composed by a hardware, a software, a database and a webpage. It showed the system concept, and the fisical implementation reached.

When the modules of this system are running jointly, users can local or remotly verify the energy from diverses monitoring points, using the internet. They analyze the data reflecting about PQ importance, and use this data to know the sources of problems or possible flaws, and, in a more conscious way, act correcting or even preventing those misbehaviors, saving money of future expenses. So, there are many reasons to companies use an energy monitoring system.

As showed in the paper, the algoritms used to calculate the PQ parameters are the traditional ones, but, as the mathematics continually reveals new formulas, faster and more efficients, new algoritms are been researched.

Also, new methods for the data transfer are beeing studied for later implementation.

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