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Diseño de un medidor de energía eléctrica bidireccional y monitoreado mediante aplicación móvil

Design of a two-way electric power meter monitoring with a mobile application

Projeto de um medidor de energia elétrica bidirecional e monitorado por aplicativo móvel

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Resumen

El presente trabajo describe el proceso de diseño, construcción e implementación de un medidor bidireccional inteligente, el cual, mediante la utilización de un sistema web, puede dar de alta y baja a usuarios finales, entendiéndose como *usuarios finales* a los clientes que reciben el servicio eléctrico. ¿Qué beneficios obtiene el usuario final? El cliente apoyado desde una aplicación instalada en su dispositivo móvil podrá generar de modo electrónico un reporte que mostrará los datos correspondientes a su consumo eléctrico durante un periodo determinado, así como uno de los pagos realizados, además de recibir información de patrones de consumo, consumo actual, estimación en moneda corriente y estado del medidor. En suma, estos datos le permitirán al usuario obtener información en tiempo real que le ayudará a tomar decisiones con respecto al mantenimiento de sus equipos electrónicos.

Se incluyen, además, los criterios que se utilizaron para la selección de las herramientas, las cuales estuvieron enfocadas en la recuperación de datos desde el medidor bidireccional con la finalidad de generar los informes orientados al usuario. Las herramientas de *software* que se utilizaron son un servidor web, un sistema operativo, lenguaje de programación, un sistema gestor de bases de datos (SGBD), entre los que destacan el Integrated Development Environment (IDE), Ionic 3, Angular 4 y Laravel. El conjunto de estas herramientas hizo posible concretar el desarrollo web y móvil.

Palabras Clave: Medidor Bidireccional Inteligente, Aplicaciones Móviles, Sistema Web, Algoritmos Flujo de datos, Servidor Web.

Abstract

The present work describes the process of design, construction and implementation of an intelligent bidirectional meter which through the use of a web system can be managed, allowing to generate high and low-end users, understanding as final users the clients which are the ones they receive electric service. What benefits does the end user get? The customer supported from an APP installed on your mobile device can generate an electronic report that will show the data corresponding to your electricity consumption during a specific period, as well as the payments made, as well as receiving information on consumption patterns , current consumption, current currency estimation and meter status, these data will allow the user to obtain the information in real time which will help him to make decisions regarding the maintenance of his electronic equipment.

We also include the criteria we use for the selection of the tools, which consist in the recovery of data from the bidirectional meter, in order to generate user-oriented reports.

What development tools are necessary? The software tools we use are the web server, operating system, programming language, SGBD, among which stand out IDE Ionic 3, Angular 4, and Laravel, the set of these tools makes it possible to specify the Web & Mobile development.

Keywords: Smart Bidirectional Meter, Mobile apps, Web System, Algorithms Data flow, Web server.

Resumo

Este artigo descreve o processo de concepção, construção e implementação de um medidor bidirecional inteligente, que, usando um sistema baseado na web pode dar aos usuários finais altos e baixos, o que significa que os usuários finais para os clientes que recebem o serviço elétrica Quais benefícios o usuário final obtém? O cliente suportado a partir de um aplicativo instalado em seu aplicativo de dispositivo móvel pode gerar eletronicamente um relatório que irá apresentar os dados de consumo de energia elétrica correspondente durante um certo período e um dos pagamentos efectuados, bem como receber os padrões de consumo de informação, o consumo corrente, estimativa em moeda corrente e estado do medidor. Em suma, estes dados permitirá que o usuário para obter informações em tempo real que irá ajudá-lo a tomar decisões sobre a manutenção de seus aparelhos eletrônicos.
os critérios utilizados para a seleção de ferramentas, que foram focadas na recuperação de dados do medidor bidirecional, a fim de gerar relatórios orientados para o utilizador também estão incluídos. ferramentas de software que foram usados são um servidor web, uma linguagem de programação, um banco de dados do sistema de gestão (DBMS), entre os quais o ambiente de desenvolvimento integrado (IDE), Ionic 3 Ângulo 4 e laravel sistema

operacional . O conjunto dessas ferramentas tornou possível especificar o desenvolvimento web e móvel.

Palavras-chave: Medidor Bidirecional Inteligente, Aplicações Móveis, Sistema Web, Algoritmos, Fluxo de Dados, Servidor Web.

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Introduction

For physics, energy is that capacity that bodies have to produce actions or heat, which manifests itself through a change, for example, a person who pushes a vehicle represents energy, like the water that runs in a river or the heat that gives off a bonfire. For years, the population has used various sources of energy: its own strength, the energy of wind and water and the exploitation of fuels such as coal, natural gas and oil (Merino, 2007).

Without a doubt, the energy and ways of producing it are problematic that will define the destiny of the world population in the 21st century. The sources of electrical energy in the world are obtained mainly from hydrocarbons. Because of the variability of geographical features around the planet, fuel consumption and development is different in each country (Estrada and Arancibia, 2010).

The objective of this document is to present the technologies that were used to achieve the collection and management of data by means of a bidirectional meter, one of the main elements being the selected client-server architecture, since this not only must be able to provide the services that the application demands, but also have the characteristics of scalability, technical support, documentation and, above all, with references that demonstrate that it has been successfully tested in similar projects.

How can the server be successfully polled? The implementation of the selected server was developed using the virtualization mode, which was installed an operating system of open source type, namely the Linux Debian version 9. The application tools and configuration of the environment were Laravel 5.5, PHP 7.1 and Apache 2. The criterion that was taken care of with special emphasis during the development of the software was the production of a dynamic web page, with an easy to use interface, simple and friendly; all of which has a direct relationship with the success of the project.

For the development of this work, a methodology divided into four stages was used: 1) electrical energy quality measurement module, 2) algorithm for data flow, 3) server and 4) mobile application. While within the organization of this article it was decided, first, to develop the state of the art of energy control systems and, as a subsection, the bi-directional sensor platform, which involves each of the component parts the system; Second, to describe the implementation and analysis of the results and, finally, to present the final conclusions.

State of the art

Measuring the consumption of electricity is an important factor for all electric companies as well as for their customers. Thanks to the electric energy meters, consumption control can be carried out. With the passage of time, hand in hand with smart devices, these meters have evolved. The so-called smart meters can be classified into two groups: 1) automatic reading meters (AMR), which only have communication in an address to the service provider, used for billing functions, and 2) the advanced measurement infrastructure (AMI, for its acronym in English), which has a bidirectional communication channel and the ability to perform some maintenance functions (Alejandro et al., 2014).

In 2014, Jeff St. John, editor of Greentech Media, visualized the use of smart meters as instruments that could allow to extend the functions of their predecessors towards the implementation of voltage optimization sensors to improve the performance of the electrical network or to monitor the health of transformers, analyze the signature of energy consumption and execute several more applications that require a great data processing. Alejandro et. al (2014) mention that the Mexican national market of smart meters is beginning to be served by a mix of large multinational companies and small local companies. Among the multinationals include Landis + Gyr (which has a plant in Reynosa, Tamaulipas), GE Electric Metering (acquired in 2015 by Clarify), Itron, Elster (with plant in the city of San Luis Potosi), Sensus (with plant in Ciudad Juárez, Chihuahua) and Holley Metering, among others.

For Accenture (2013), the evolution of smart meters will be determined by the characteristics of the market and the generating companies. In the United States, it is desired that the meters help to carry out tasks of management of power failures and increases in the reliability of the network, while in Europe the approach is greater towards compliance with mandatory regulations and the increase of capabilities to help the user in the administration of their consumption. Manufacturers such as Itron (2014) offer smart meters with bidirectional energy measurement capabilities, load profiles that can be recorded at programmable intervals, measurement of time of use and, in some models, communication by ZigBee protocol to the user's home network. On the other hand, Aclara (2014) offers these same general characteristics plus the possibility of setting limits for the user's peak demand. While Landis + Gyr (2014) offers energy measurement in four quadrants with resolution of thousandths of unity and protection against attempts to alter the meter, in addition to having a meter model certified in Mexico (LAPEM). Other companies such as Schweitzer Engineering Laboratories (2015) have bidirectional meter lines that include communication through DNP3 standards, Ethernet, among others, and have the ability to predict the demand for alarm activation. ION (2015) and Siemens (2015), in addition to communication capabilities using DNP3 and Ethernet and demand prediction analysis, include in their meters the ability to perform harmonic analysis up to component 31 and in some cases up to component 63 (Siemens, 2011).

Xudong, Shuqing, Peiyu and Lei (2014) proposed a bi-directional intelligent meter composed internally of electric power measurement modules, power measurement, information display screen and a power supply. The power measurement module was connected to the public electricity network and the user's network. This had a microcontroller that processed the information from the power measurement module and sent it to the screen. The real-time measurement of the energy consumption took into account the power consumed from the public network and the power delivered by the user's system to the public network. Real-time and historical measurements of energy consumption could be displayed on the screen.

In the study presented by Jhang, Sampson and McKeown (2014), a system and several methods of developing electricity consumption profiles by means of data exchange coding applicable to an AMI with smart meters are described. The described system transmits messages with information on the consumption or other information of the household appliances of a house, as well as of servers or controllers, and includes the implementation of an intelligent energy profile with coding based on JavaScript object notation (JSON, for its acronym in English). The system includes at least one processor that is configured to store and execute instructions to control devices within a home area network (HAN). The system has a central server, which is configured to establish communication with at least one network that contains an energy service interface (ESI). This network can be wired, wireless, a combination of both, local or wide area, and even Internet. The ESI device, on the other hand, can be an intelligent meter or another type that allows to accept instructions and perform operations to make measurements, regulate consumption or display information about it. Likewise, the ESI can be in communication with at least one intelligent device via HAN or another type of network. And among the intelligent devices that can be controlled are the heaters, air conditioners and other appliances that have a communication link with the ESI.

Bidirectional meter platform

The base platform of the bidirectional meter with commercial electric power measurement devices can be represented with the block diagram shown in figure 1. The interconnection of these blocks represents the functionality of the bidirectional meter designed according to the specifications shown below.

Figura 1. Plataforma base del medidor bidireccional con dispositivos de medición de energía eléctrica comerciales

Fuente: Elaboración propia

Module of measurements of the quality of electrical energy

It consists of signal conditioning circuits for the edition of effective voltage in the single-phase or two-phase network and the current demanded by the alternating current (AC) load connected to the network; considers both the energy supplied by the Federal Electricity Commission (FCE) and the energy generated by the photovoltaic system interconnected to the network. All connections and measurements made are made in accordance with the CFE regulations. After the signal conditioning stage, the analog data are converted to digital data through the MCP3008 circuit.

Algorithms for the data flow

Once the network voltage and current in the load are measured, through the signal conditioning circuit, these data are transferred to the platform for data processing by means of a Raspberry Pi3, through the Serial Peripheral Interface protocol (SPI) In this platform the necessary code is developed so that, from the measurements of the voltage and the current, the parameters of quality of the electrical energy, such as the total harmonic distortion (THD), the power factor (FP), average power and reactive power.

Server

The server is running within an instance of a virtual private server (VPS), implemented in the Google Cloud Platform platform, in which the Linux Debian 9 operating system was installed, with 30 GB of hard disk memory and 2 GB of RAM. It was built with the help of a framework for real-time applications programmed in Node.js, a modern interpreter with a very active community, which allows to execute the Javascript programming language inside the server. The models that were used for this prototype were two: one for the measurements that the meters send (Measurement.js) and another one for the same meters (Raspberry.js). The model of the measurements includes the different values to be determined: the RMS voltage, the RMS current, the instantaneous power and the harmonic distortion, among others. The model for the meters includes information such as the unique identifier of the meter, the related measurements, the amount of energy consumed, the charge and the cutoff date of the service.

The implementation of the server allowed the development of a dynamic website, which, supported by the type of wireless communication, offers the possibility, through the bidirectional meter, to send information to the user about consumption patterns, consumption estimation and status from the same meter. Figure 2 shows the view obtained by the client.

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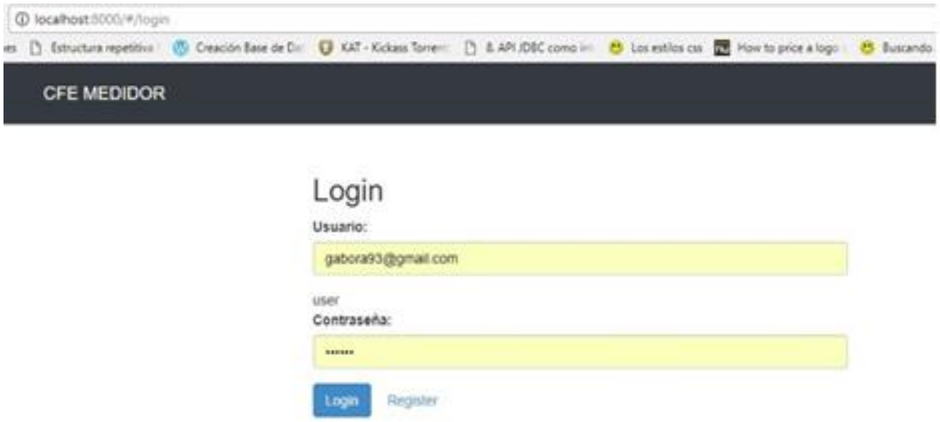
Figura 2. Vista del cliente al entrar al sitio web. El usuario deberá autenticarse por medio de usuario y contraseña

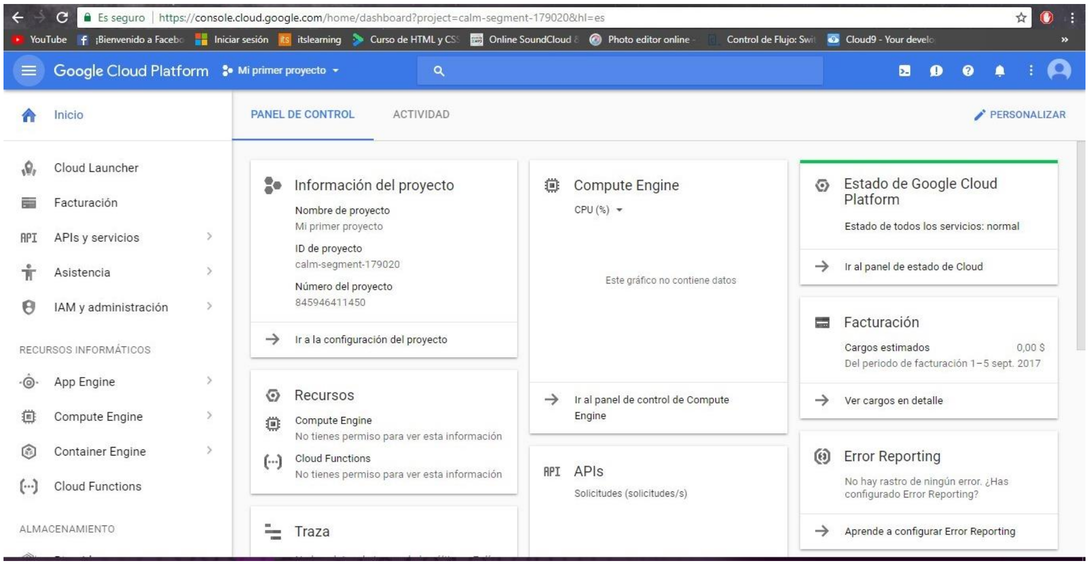


Fuente: Elaboración propia

Regarding the configuration of the server, the first thing to do is create an account in Google Cloud Platform. Once the access procedure is performed, an interface called Main Tools Menu will be displayed. In this window you can see the different tools to work and define the main configuration.

There, for the use of the virtual machine (VM, for its acronym in English), you must indicate in the virtual server Google Cloud Platform that you want to run a VM instance. Immediately an interface will be displayed in which you can define the parameters of the VM: the name of the operating system, RAM and processor, as well as establish FTP and HTTP access. Once this is done, we will continue with the installation of the following services: Laravel, PHP, MySQL, Apache and Node.JS

Figura 3. Interfaz principal en el servidor virtual utilizando el servicio de Google Cloud Platform



Fuente: Google Cloud Platform (2018)

App (end user)

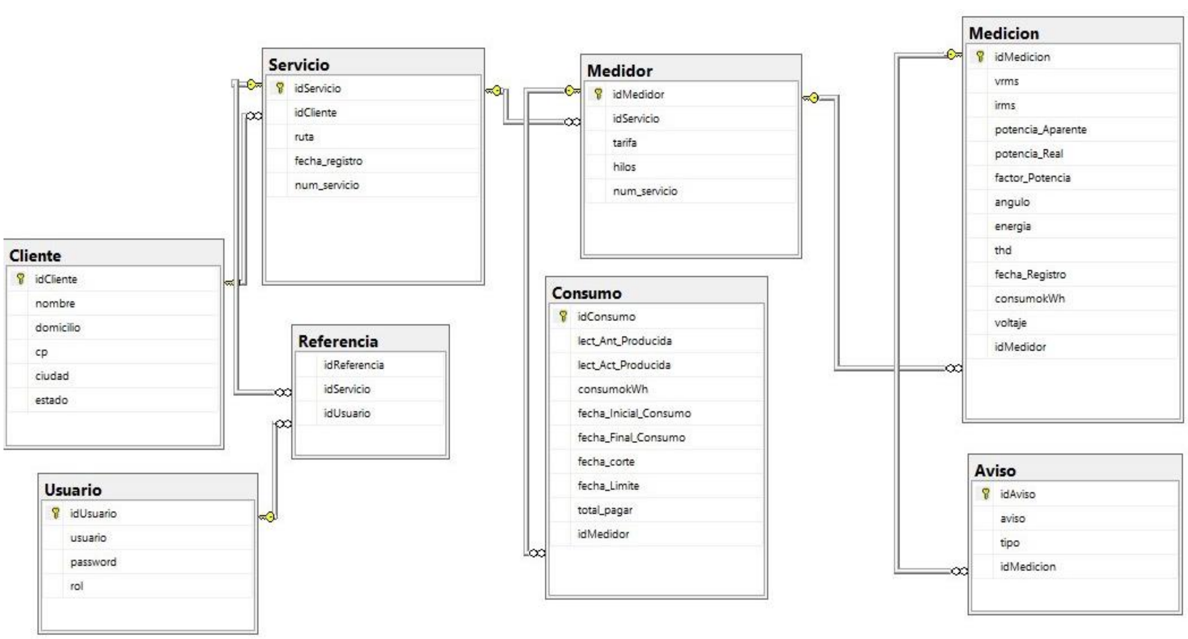
In order for the end user to receive notifications about energy consumption and other notices of interest, push notifications are used (these notifications are sent thanks to a Google service called Firebase). The server has a service that communicates with the Firebase application programming interface (API) to send them.

The app is a system that has an interface that allows you to establish authentication on the server. Once the communication with the server is established, this application is able to provide data regarding the electricity consumption. The knowledge of these elements will allow the user to optimize their consumption, since they will be able to establish maintenance plans in the electrical equipment in their home and, if necessary, the replacement of obsolete equipment.

The data of the app is stored in a database, which is hosted on a server with services in the cloud. This database is updated constantly thanks to the data provided by the different meters, located in different geographical areas.

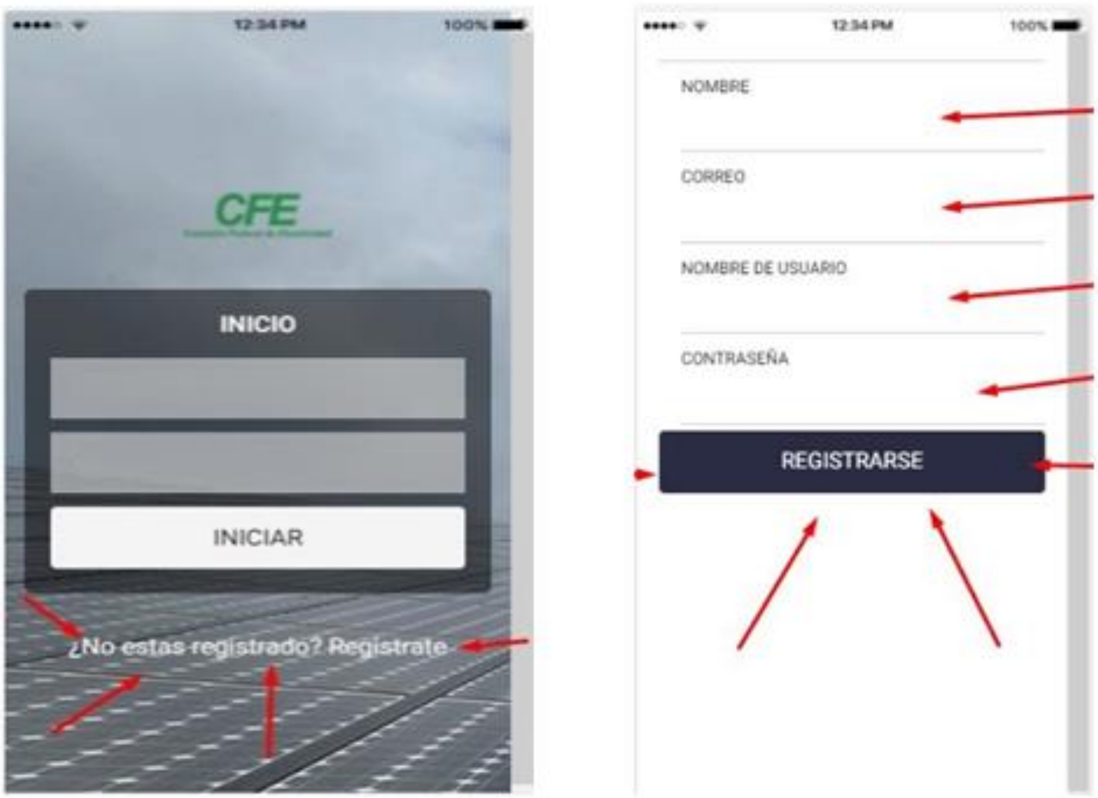
In order to define the database, the first thing that was done was to carry out interviews with the figure of the owner of the system. The result of such interviews was translated into the definition of the entities and their attributes. Once the entities were defined, they were subjected to a normalization process in 1FN, 2FN, 3FN and 4FN, which ensures that the schematic design is efficient, free of redundancy and allows the storage of data in an optimal way. From this point on, everything is ready to be able to select the database management system (DBMS) and be able to start building the database itself; here it is considered that the most suitable for this activity is MySQL, using the relational model. Before going to the specifications of the model that was designed, in figure 4 you can see the design of it, while in figure 5 and figure 6 some other interfaces of the app are shown.

Figura 4. Modelo E-R de las tablas que corresponden a la base de datos



Fuente: Elaboración propia

Figura 5. Interfaces de la *app* que son utilizadas para crear el usuario, paso que permitirá la autenticación con el servicio provisto por el servidor



Fuente: Elaboración propia

Once the user has achieved authentication, you can view the following data: general user, current measurements and the display of parameters such as apparent power, real power, power factor, angle, energy Thd, consumption KW / h and voltage.

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Figura 6. Interfaz de la *app* que muestra los principales parámetros obtenidos del servidor.

Fuente: Elaboración propia

Electricity quality measurement module

The module for the measurements of the electric power quality of the voltage and AC with the bidirectional meter consists of signal conditioning circuits and data acquisition with the reduced Raspberry Pi board. This module can be divided into different stages, as shown in the block diagram shown in figure 7.

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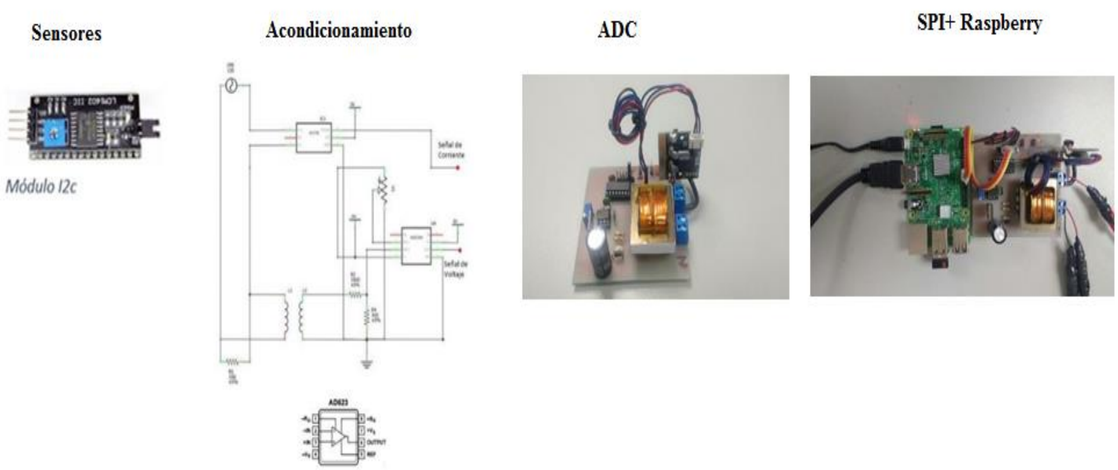
Figura 7. Diagrama a bloques del módulo para las mediciones de la calidad de la energía eléctrica y adquisición de datos en el medidor bidireccional



Fuente: Elaboración propia

Sensors and signal conditioning

Voltage sensor

For the measurement of the single-phase voltage, a 10: 1 reducing transformer is used in order to keep the earth of the signal conditioning circuit and the neutral isolated. In the secondary of the transformer, two resistors are connected in series (y) to form a voltage divider that serves as a voltage sensor.

This signal obtained from the voltage divider is applied to the non-inverting input of the AD623 instrumentation amplifier to subtract it with a negative voltage supplied by a precision potentiometer connected to the inverting input of the same op amp. The potentiometer is adjusted to move the offset of the sinusoidal signal and, in this way, to achieve that the peak voltage of the negative half cycle is zero, which allows obtaining a signal only with positive values in the output of the operational amplifier.

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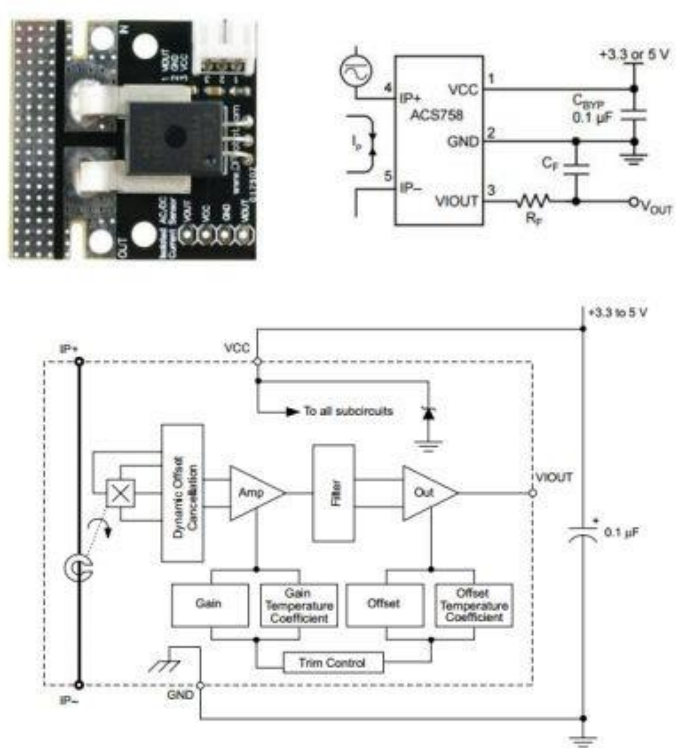
Current sensor

To measure the intensity of the current in the load connected to the network, a linear Hall effect sensor is used, connected in series with the load and delivery of 40 mV per ampere measured. Figure 8 shows the image of the sensor and its block diagram, whose main characteristics are the following***:***

- Current Range: -50 A to 50 A.
- Output Range: 0 V to +5 V.
- Sensitivity: 40 mV / A.
- Electrical offset: 2.5 V (ideal).
- Supply voltage: 3 V to 5.5 V.
- Bandwidth: 120 KHz.
- Output voltage proportional to direct current (AC) or AC.

Figura 8. Sensor de corriente ACS758 y su diagrama a bloques



Fuente: Elaboración propia

Data acquisition

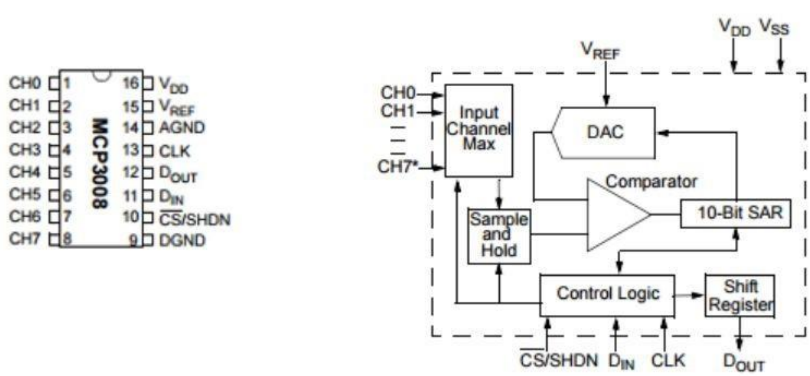
The stage developed for the acquisition of data, that is, the circuit used for the Raspberry Pi 3 to read the voltage and current values provided by the signal conditioning stage, is done through an analog signal converter circuit. digital (ADC, for its acronym in English) and the SPI protocol of the same Raspberry Pi 3.

ADC converter

The circuit used for the conversion of the analog signals obtained in the signal conditioning stage, that is, the voltage at the output (proportional to the network voltage) of the AD623 instrumentation amplifier and the output voltage (proportional to the current intensity in the load) of the ACS758 current sensor, is the ADC MCP3008. Figure 9 shows the pin distribution of this circuit and its block diagram. The main characteristics of this ADC are the following:

- 10-bit resolution.
- Four channels for analog inputs (simple or differential).
- SPI serial interface.
- Supply voltage from 2.7 V to 5.5 V.
- Low power CMOS technology.
- Operating temperature: -40 ° C to +85 ° C.

Figura 9. Distribución de pines y diagrama a bloques del circuito convertidor analógico-digital MCP3008

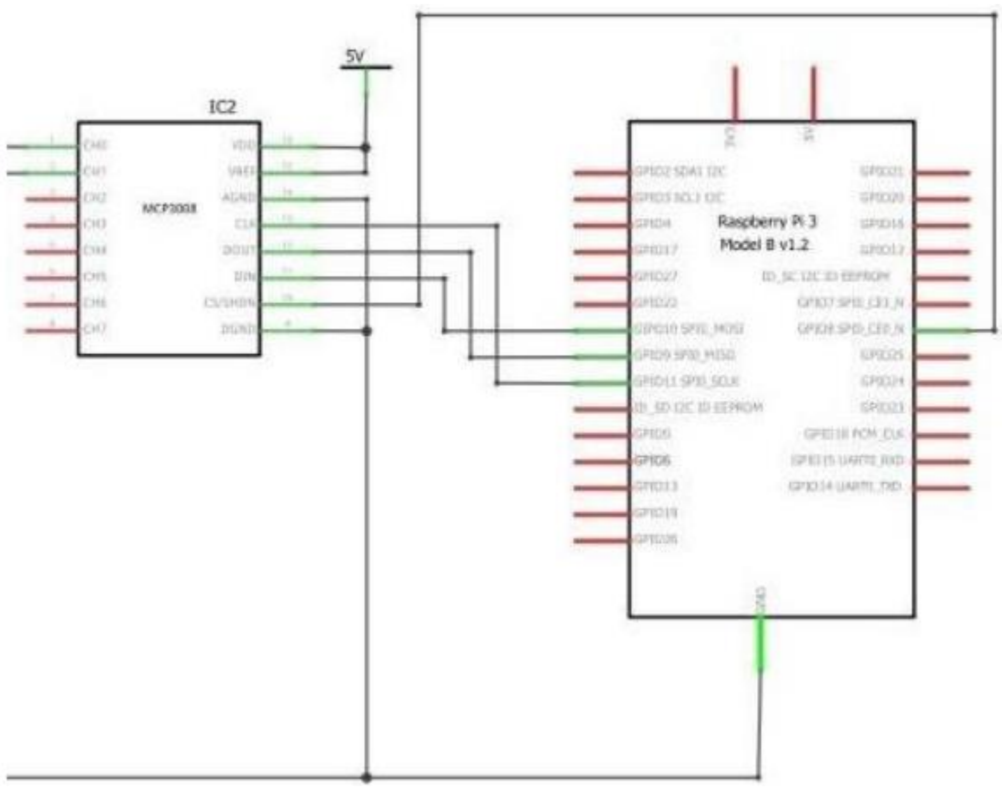


Fuente: Elaboración propia

SPI communication of the Raspberry Pi 3

The control signals of the ADC circuit MCP3008, pins 10, 11, 12 and 13, are connected to the Raspberry Pi 3 and used to capture the information of the sensors already in digital form through the SPI protocol. This information is stored in a local database.

Figura 10. Diagrama esquemático de las conexiones del ADC MCP3008 a la Raspberry Pi 3 para la etapa de adquisición de datos en el medidor bidireccional



Fuente: Elaboración propia

Digital interface of the embedded type for the expansion of measurement functions

The proposed prototype of the bi-directional meter is an interface interconnected in the common node with the AC supply network of the CFE and the microinverter output of the photovoltaic system interconnected in the network. This allows the solar panel system to operate in parallel to the network provided by the CFE, so that the power can flow in both directions between the network and the interface. Its functions are the following:

- Disconnection means for safety and maintenance.
- Measurement between the system, the local load and the network.
- Phase the flow produced by the panel together with that provided by the CFE.

Algorithm for the data flow

From the measurements of voltage and current and data acquisition, the code is developed to calculate the parameters for measuring the quality of electric power. This code is developed in Python for Raspberry Pi 3, according to the following data flow:

1. Start.
2. Main program: Logic.py.
3. Function that returns the calculation of the parameters: getParams (), inside the calc.py program.
4. daq.py program:
    a) Function that returns the data taken from the sensors: data ().
    b) Configure SPI port.
    c) Access the ADC records to obtain the data.
5. Return to the calc.py program:
    a) Apply filter to the data, when required.
    b) Calculate the parameters (real power, apparent power, power factor, phase angle and THD).
6. Return to the main Logic.py program to print the results on the screen.
7. Function that sends the data to the server: send (), inside the comm.py program.

Figure 11 shows the code implemented for the simulation of parameter calculation with Matlab.

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Figura 11. Ejemplo del código desarrollado en Matlab para el cálculo de los parámetros

```
fs = 10000;              %Frecuencia de Muestreo (Hz)
t = 0:1/fs:0.5-1/fs;      %Muestra de 0.5 segundos
%SIGNAL
x = 10*sin(2*pi*60*t+50*pi/180) + 0.33*sin(2*pi*120*t)+ .11*sin(2*pi*180*t);  %Componente de 60 Hz
x = awgn(x,10,'measured');  %Señal con ruido
%---------------------
n = length(x);           %Tamaño de ventanda para analizar
%n = pow2(nextpow2(m));  %Transform length
y = fft(x,n);               %DFT
y_scaled = y/n;          %Escalamiento de la señal.
f = (0:n-1)*(fs/n);      %Rango de frecuencia
%power = y.*conj(y)/n;   %Potencia de la DFT
plot(f,abs(y_scaled));
axis([0 200 0 6]);
xlabel('Frequency (Hz)');
ylabel('Magnitud');
title('{\bf Periodogram}');
%Encuentra la componente fundamental de la señal
index_freq = find(y_scaled(1:length(y_scaled)/2) == max(y_scaled(1:length(y_scaled)/2)));
ind = index_freq(1)
%frecuencia_senal = ind*fs/length(y_scaled)
frecuencia_senal = f(ind)
%Calculo de desfase
x2 = 220*sin(2*pi*60*t+30*pi/180);
x2 = awgn(x2,10,'measured');
y2 = fft(x2,n);
y_phase = angle(y(ind));
y2_phase = angle(y2(ind));
shift = abs(y_phase-y2_phase)*180/pi

mag_fundamental = max(abs(y))/n          %MAgnitud de la componente fundamental
%sum(abs(y_scaled))      %Resultado de la suma de las magnitudes de todas las componentes

THD = 100*sqrt((abs(y_scaled(ind*2-1))^2 + abs(y_scaled(ind*3-2))^2 + abs(y_scaled(ind*4-3))^2 + abs(
```

Fuente: Elaboración propia

Results

Figure 12 shows the results obtained from the instantaneous values of voltage and current using a resistive circuit composed of 700 W bulbs.

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Figura 12. Imagen que ilustra el circuito resistivo compuesto por bombillas de 700 W

Fuente: Elaboración propia

Next, the results of the measurements shown on the mobile device are presented in table 1 by means of the app developed.

Tabla 1. Resultados obtenidos en la prueba de laboratorio

Ultima conexión	Vrms	Irms	Potencia aparente	Potencia real	Factor potencia	Ángulo	Energía	Thd
23:11:39	125.82	0.59	74.33	71.83	0.97	14.88	0.05	1.83
23:14:21	125.49	1.01	127.17	125.63	0.99	8.92	0.03	2.9
23:15:44	124.35	0.6	74.16	71.08	0.96	16.53	0.05	2.71
23:19:00	126.7	1.03	130.52	125.63	0.99	10.34	0.02	1.9

Fuente: Elaboración propia

The hardware used in the measurements was composed by a Raspberry Pi3, a 16 x 4 LCD screen, dupont cables, PCB board, 9 v micro usb charger, 12 C module and 12 gauge red and black awg cable.

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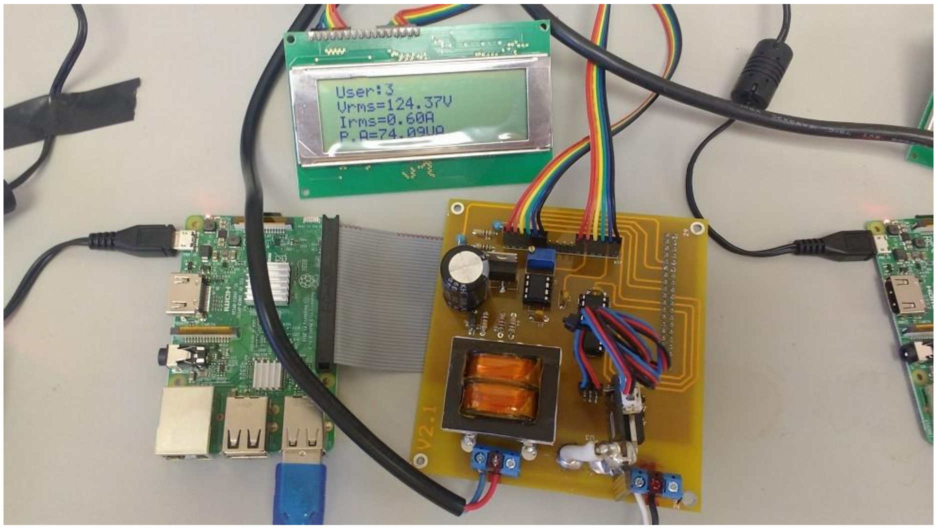
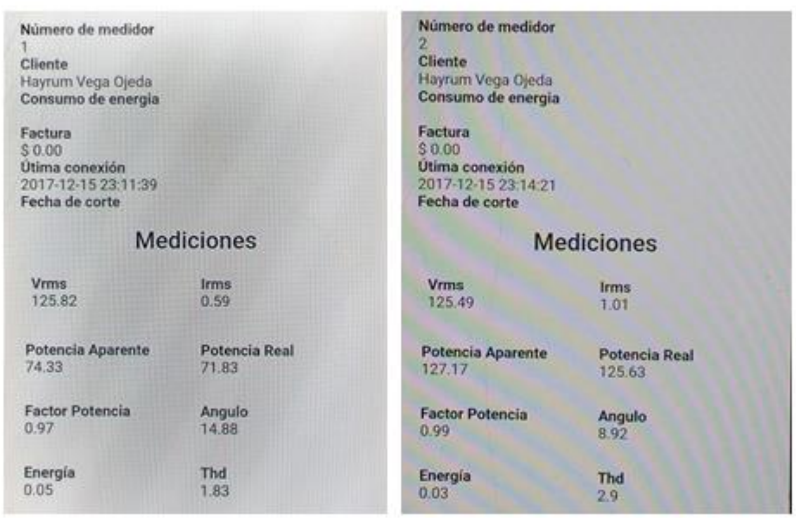
Figura 13. Principales componentes que permiten la medición de los valores registrados por el medidor bidireccional



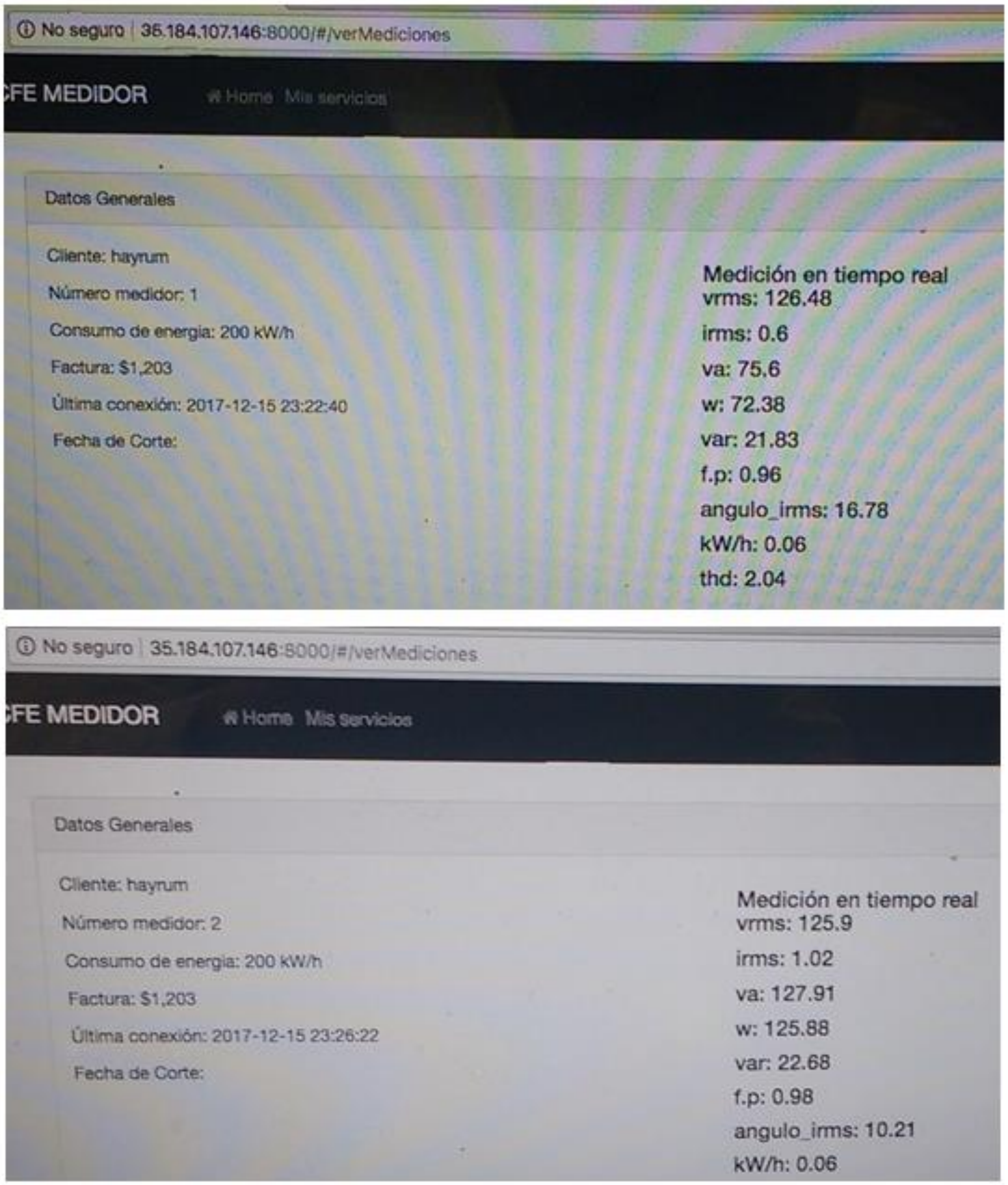
Fuente: Elaboración propia

Figura 14. Muestra de los registros obtenidos desde la *app*



Fuente: Elaboración propia

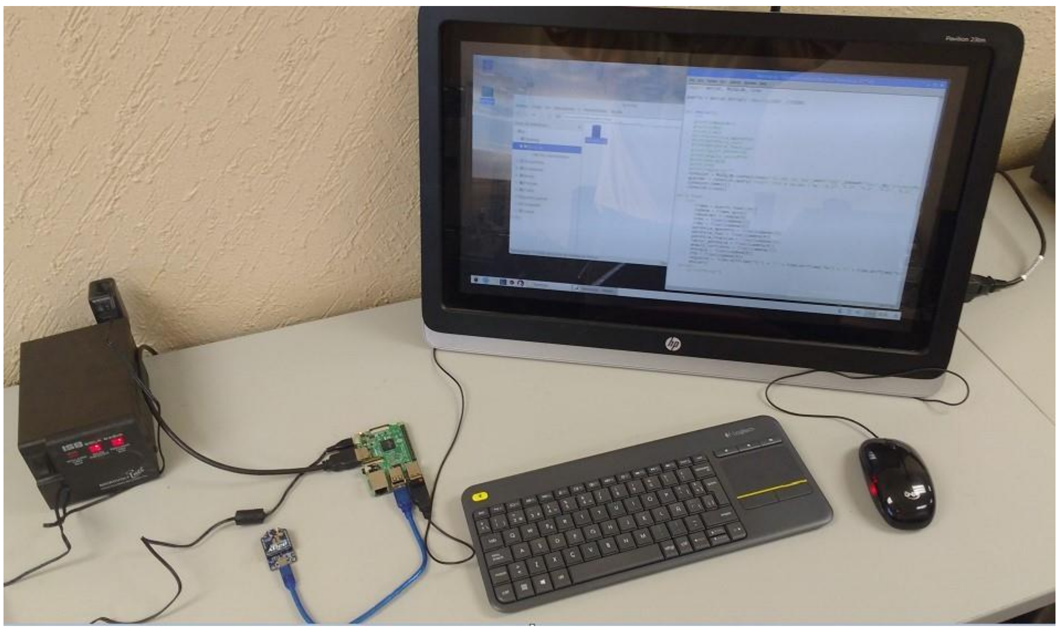
Figura 15. Muestra de los valores registrados por el medidor bidireccional en la página web dinámica



Fuente: Elaboración propia

Next, the communication that is given wirelessly and how the data is sent to the web server is illustrated.

Figura 16. Envío de datos por medio del módulo inalámbrico hacia el servidor web



Fuente: Elaboración propia

During the phase of implementation and analysis of results, laboratory tests were carried out and these were carried out as progress was made in the design of the circuit for the conditioning of the signal and the acquisition of data, as well as during the selection of the platform for wireless communication. With respect to the selection of sensors, various tests were carried out through the implementation of electronic circuits. The result of the tests determined that the ideal components with the current sensor are those of the ACS758 due to the linearity that it presents, the ease of connection, the precision in the measurement and the cost. With respect to the voltage sensor, a step-down transformer was used to isolate the earth from the power circuit and the control circuit, as well as a voltage divider. An operational amplifier was also selected for the final prototype, which acts as an AD623 instrumentation amplifier.

To achieve data acquisition, various circuits were implemented; Highlights, mainly, the tests carried out with Arduino UNO, diverse ADC converters, PICI8F4550 microcontrollers and LCD screens, due to the compatibility with the PSI protocol of the Raspberry Pi 3, which was chosen to achieve said data acquisition of the ADC MCP3008 circuit. It is important to mention that the code that was implemented was developed in Python through various free platforms that allowed the use of the server.

To achieve data visualization, several tests were carried out with several LCD screens, which showed compatibility with the Raspberry Pi 3, which communicates with the sensors and is aided by the MC3008 integrated circuit. This circuit is an 8 channel ADC, which can communicate through the SPI interface. And to make the tests the Python library developed by Adafruit was used.

Likewise, the attributes of Raspberry 3 were used, which has a Wi-Fi module, an attribute that allowed permanent connectivity to the Internet. Thanks to this, the Raspberry can establish a communication with the server, using a message queue (Message Queue) to transmit the data that is emanating from the sensors.

While to get the server ready, it was necessary to have a VPS that would count in turn with a service provider, such as Amazon or Digital Ocean. Using a VPS, a database was installed using MySQL, a server for MQ and a web server. It is important to mention that the VPS has two functions; one of them is to listen to the data that the Raspberry Pi 3 sends, and the other function is to provide an interface for the application program and thus be able to develop other applications with the information collected.

For the development of the user interface, an application was produced through the Android IDE. This app shows the user the current consumption of the meters that are registered, as well as the service history.

In addition, the administrators of the service use a web system, this being an interface that allows to register and download the meters, as well as to obtain the consumption of a certain area.

In the development the IDE Ionic 3 and Angular 4 were required, with which the extraction of the data of the bidirectional meter was achieved through the services provided by Laravel Node JS. This is required because it is an execution environment for JavaScript, built with the Java Script V8 engine, which belongs to Chrome Node JS and uses an input / output operations model that does not present restrictions, in addition to being oriented to events, being these characteristics those that make it a light tool and allow to maximize its efficiency. IONIC, likewise, is required because it is a framework that belongs to the free software segment; It was used to develop hybrid and multiplatform applications. This tool allows the use of hyper text languages, such as HTML and CSS.

Table 2 shows the results obtained from the instantaneous voltage and current values using a resistive circuit by 70 w bulbs.

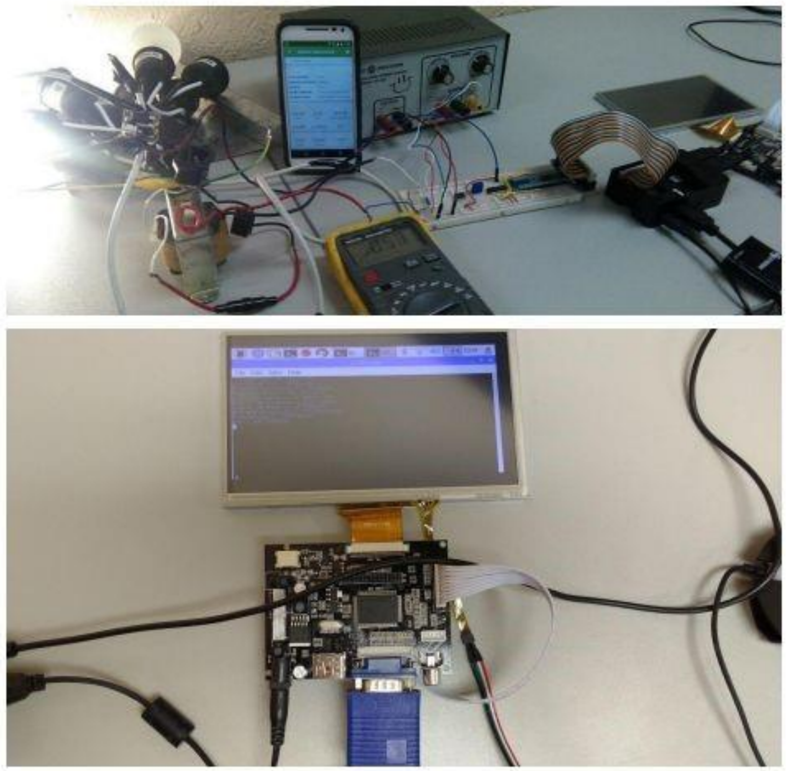
Tabla 2. Pruebas de adquisición de datos

Bombillas	Vrms	Irms	FP	Desfase	P. activa	P. reactiva	P. aparente
6	128.88	3.45	1	0	444.98	0	444.98
5	128.97	2.87	1	0.02	370.15	0	370.15
4	128.88	2.31	1	0.29	297.58	0	297.58
3	128.79	1.73	1	0.02	222.33	0	222.33
2	129.15	1.14	1	0	147.71	0	147.71
1	129.33	0.56	1	0.03	72.56	0	72.56

Fuente: Elaboración propia

On the other hand, Figure 17 shows the tests performed in laboratories.

Figura 17. Pruebas realizadas en laboratorio



Fuente: Elaboración propia

Using the analog ports of the microcontroller (A0, A1), the instantaneous voltage and current values were obtained, which were tabulated in the Excel table, while the instantaneous power was calculated in the microcontroller as the product of the current by the voltage. Thus, the presented sample is the result of applying a purely resistive load to the circuit. In such a way that the voltage should be shown in phase with the current, but, because the load is purely resistive, in effect, the relationship between current and voltage is linear.

Conclusions

Regarding the general objective of the research, namely to develop a commercial prototype of intelligent meter, an auxiliary in the administration of bidirectional power supply service, it is considered that it has been carried out successfully, since it was possible to design and evaluate the functionality of the meter. Thanks to this meter measurements were obtained and reports were generated by the end user, in addition to being able to administer via remote server each one of the meters. It should be noted that this project was developed in close relationship with other institutions of higher education, such as the Technological Institute of Hermosillo and the State University of Sonora (UES). In this paper the point of view of the UES is exposed, part that committed itself to the following deliverables:

- Develop a software platform that allows the wireless communication module to achieve the sending of data such as consumption patterns, as well as the status of the meter.
- Develop a mobile application to establish a communication with the server and also inform the end user of the consumption profile of the monitored installation, as well as inform about the electric charges that are directly affecting your billing receipt.

This objective and this commitment were carried out by the UES in a 100%, and the functionality was validated in collaboration with the Technological Institute of Sonora.

It is expected that, with the implementation of the bidirectional meter proposed and its monitoring through the developed mobile application, end users can take greater control over their energy consumption in real time from wherever they are located. The above can help raise awareness about energy consumption and thus make sound decisions that allow the optimization of the electrical resource. It is expected that the information presented in this document will broaden the panorama of the data recovery process from the bidirectional meter to the proposed platforms such as the web server and the end user's app.

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