Management System Prototype to Contribute with Energetic Efficiency of an Electric Iron

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Abstract
In this paper, a management system prototype in an electric iron is presented with the purpose of monitoring tension, current, energy and costs parameters, besides of controlling the real time turning on and off using a web page. Its objective is to reduce electric energy consumption to contribute with energy efficiency processes, without decreasing user's life quality. The prototype was developed with essential hardware and software components. Regarding hardware, Arduino® plaque was implemented along with Ethernet Shield card, which allows to have an IP direction and as an effect, a bidirectional communication, additionally it is joined to a data acquisition system that takes measures of the well calibrated electrical parameters. Regarding the software, a web application was developed using a set of languages, which makes electrical measures monitoring and control possible, by using PLC power line communication. Internet of things is used in this investigation since there is work on smarts devices and there is user-technology interaction, with the aim of giving accurate information that allows to take decisions that improve the life quality and that the population acquires higher awareness on electric energy saving.

Keywords: Internet of Things, Arduino®, Power Line Communication, Electric Iron

1. Introduction

Lots of residences actually count with domestic systems which are considered as the beginning of domestic technification, using “elements that provide some automatization level” (Snyder, Gunther, & Griffin, 2012). Technology advances such as “Internet of things”, makes that devices can be remotely managed with internet connection trough a virtual platform. (Méndez, 2015). In order to have interaction between objects using internet, an internet protocol (IP) is required so it can be integral part of system with the objective of monitoring and controlling them, which allows that similar networks exchange information among them (Luis & Ortiz, 2012). Internet protocol (IP) is potential allows technological convergence to use a single infrastructure and lend multiple services (Luis & Ortiz, 2012).

Given the worldwide concern about the growing energy demand and climatic change, energetic sector has focused its efforts on energetic efficiency (Agencia Chilena de Eficiencia Energetica, 2013). In order to achieve its goal, energy efficiency requires the most advanced technology to control residential devices from any electronic appliance.
A study made in Ecuador found that one of the most common home accident worldwide is caused by electric iron (Llivisaca, 2010). Which is why an electric iron prototype was made with purpose of monitoring parameters as tension, current, energy, cost, position and movement, besides controlling the real time turning off through a web page. The objective is to reduce energy consumption by increasing user’s lifestyle quality developing energy efficiency processes, all the above with Internet of Things, which incorporates smart devices with purpose of providing information that allows decision making (Alcaraz, 2016).

2. State of Art

Taking into account that there is no such thing as “Smart iron or IP” in the market, sockets are analyzed, they develop actions over the charges connected to network, such as an iron, with purpose of verifying its state through a control application and turning it on and off remotely (Acosta & Padilla, 2015). This devices facilitate having control over daily routines by controlling each home appliance, so homes become more dynamic, functional and appropriate for modern lifestyles, this devices let users control in a smart way their home devices (Edimax, 2016). Some socket devices offered in the market are shown in Table 1.

Table 1. Characteristics from Sockets offered in market

Brand	Characteristics	Integrated energy measure	Requires Android App	Timer
Energy ego	Turns on and off devices individually, real time monitoring	Yes	Yes	Yes
Edimax	Turns on and off, manual or programmed control, email notification	No	Yes	Yes
TP-Link	Easy configuration, real time monitoring, consumption summary, control from any place through internet	Yes	Yes	Yes
Belkin	Connects devices to Wifi network, personalized state program, controls on and off turning	Yes	Yes	Yes
Wattio	Devices consumption control, avoids unnneccesary consumption, alerts on anormal consumption.	Yes	Yes	No

Taking into account these devices and evaluating each of their characteristics, the following lacks for user were identified:

- The functioning of these sockets is directed to a huge amount of home appliances, which generates an extra cost when buying many sockets.
- Devices that integrate communication modules do it through a mobile device app, which is not appropriate for other type of devices
- There is no control, monitor and supervision of a single device equally, which means that there is no general information of all the devices at the same time for the user.

The prototype proposed in this paper offers the possibility of turning on and off an electric iron, besides of observing the real time energy consumption, allowing the users to know the cost of consumed energy in different periods, likewise, the functioning of prototype allows anyone to use it without installing any application because it was developed using HTTP protocol.

3. Materials and methods

This section shows how the prototype was implemented for the measuring and control system, beginning with selection of the required devices according to design, development and construction.

3.1. Device Selection

The following main components were stablished to select devices: PLC communication, hardware platform, Ethernet, energy measurer, current sensor, tensile tester, actuator and inertial sensor. It is shown below the way which they were selected:

PLC Communication Adaptor

PLC (Power Line Communication) technology is capable of transmiting data through the electric network, which is why it can be extended or share Internet connection to any PLC receptor located in same electric network (Serna, 2011). Among the existing products in market adaptors such as Powerline 1200 from Netgear, Powerline AV500Nano from Tplink or Powerline PLEK 500 from Cisco were found. After developed study, Powerline AV500 Nano (Tp-Link, 2016) was chosen because of its versatility, low cost and fast data transference which is enough for prototype, it equally gives the possibility of being a Plug and Play system, which eases the operation and functioning of this adaptor.

Hardware Platform

In order to implement the design surrounding and measuring system simulation with Arduino® it is necessary to stablish which boards exist, among which are Arduino® One, Yun, Leonardo, Due, Mega, Nano, among others. The analyzed boards offer benefits according to the type of micro controller they use, type of port, memory, voltage outputs, digital pins, analog pins, among others. For the energy measure application for an iron, the most appropriate one was Arduino Nano due to its compact size, and it also has an adequate memory for application and the possibility of obtaining an SPI (Serial Peripheral Interface) communication with other devices (Estados Unidos Patente nº US7069352 B2, 2006).

Ethernet

The local area network technology (LAN) Ethernet was designed to transport data with high speed and short distances and it is adjusted to applications where local communication media must carry a dense traffic of packaged data (Gracia Marin, 2016).
The methodology used in the design was divided in analyzing two board types that can give Arduino® internet connection, considering characteristics such as price, dimensions, data transfer speed, Ethernet Shield plaques and ENC28J60, when initial tests were made on ENC28J60, it behaved properly, but as the code increased proportionally to memory, it did not develop the process nicely. Besides, Ethernet Shield gave much more memory, which helped to improve data manipulation remotely due to the better send and reception of data that this plaque provides.

Power Meter

Based on the huge amount of meters that Analog Devices (Analog Devices, 2016) enterprise offers, and analyzing variables as rules, types of measures, main characteristics, among others. It was decided that ADE 7763 was the measure circuit to be used, it consists of a digital integral chip that creates an interface with some current sensor that has 2 channels (current and voltage), each one with a programmable earning amplifier and error range lower than 0,1% in energy measure. Likewise, it counts with a temperature sensor to help with apparent energy measure, active energy, voltage signal and effective values both current and voltage. ADE 7763 has tension and phase digital calibration so as a serial interphase compatible for SPI communication.

Current sensor

As told in (González, 2008) the current sensor turns current magnitude in a distribution line into an equivalent current level. There are different types of current sensors, which differentiate because of their dynamic range and bandwidth, which is why the four most common sensors are: “Shunt” resistance which provides an accurate and direct measure of current (Meneghini, Cester, Mura, Zanoni, & Meneghesso, 2014). Current Trasformer (TC) which transforms primary is current into the one of the secondary of less value (Enriquez, 2015). Hall Effect sensor which is based on current is fall through a lead (Donato, Pulvirenti, Capponi, & Scarcella, 2016), and Rogowski Coil that consists on a coil rolled in a nonmetallic material nucleus (Enriquez, 2015).

Hall Effect current sensor is used in this application because Rogowski bulb and TC is comparable with it, additionally Shunt Resistance is heating does not make it a reasonable option. ACS 714 was the chosen current sensor mainly because it offers different measure ranges among which are ±5, ±20, ±30 Amps.

Tension Measurement element.

Tension divider is a measurement method designed to measure high tensions, it is a circuit that distributes one source's tension in two or more impedances connected in series, it is composed by passive elements as resistances and capacitors that help to measure impulse type signals, direct current and alternate current (Universidad Distrital Francisco José de Caldas, 2010).

Actuator

The relay is defined as device that works to produce certain modifications as some electrical circuit conditions affect it. Lots of electrical devices adapt to this definition, from electromechanical relays up to contactors, the first ones are compact, which means they do not have mobile parts and they are even designed by one single piece with numerous terminals, among them there are. Triacs, that can work with CA and CC, but they will not stop current flows unless it falls under the threshold (París, 2003). It was decided to work with SFK-112DM electromechanical relay for the electric iron, it supports up to 20A.

Inertial Sensor

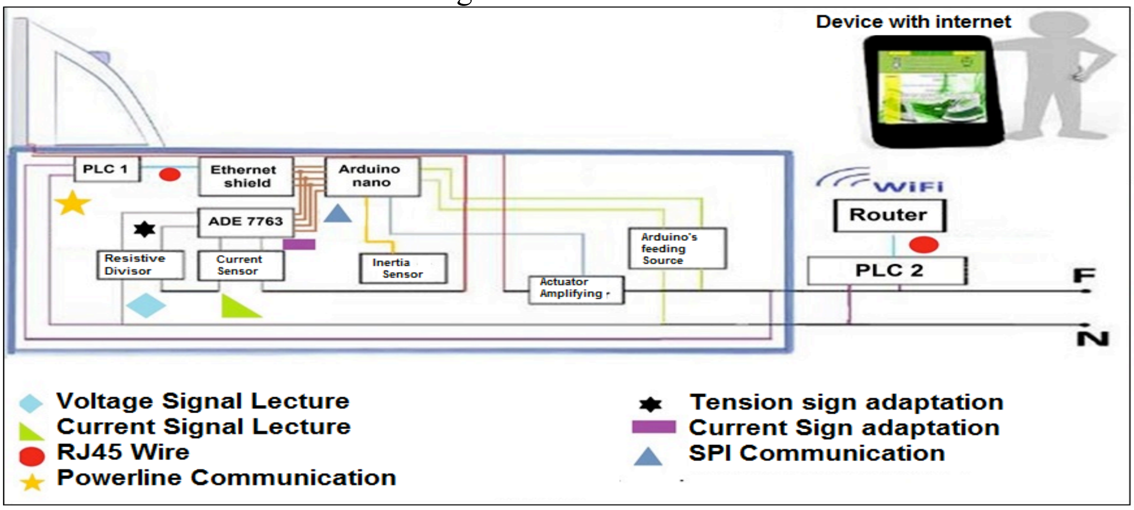
Analysis were made over inertial sensors that are based on acceleration and angular speed variations which are obtained through an accelerometer who provides the acceleration caused by a movement through the framework edge and gyroscope shows how an angle changes in time (Espín, 2010).

According to this, five types of accelerometers, gyroscopes or accelerometer-gyroscope were analyzed among which are L3GD20 sensor, MMA 7455, MPU 6050 and ADXL345, taking into account electric, economic, number of edges and other characteristics, it was decided to work with MPU-6050 because it has a fusion between two sensors with an error margin smaller than others, so the best characteristics can be taken from each one of them and achieve an easier work with Arduino®.

3.2. Design

Figure 1, shows graphically the scheme of electric iron where tension, current and energy signals are taken and adequate, a relay is used as actuator and Ethernet with PLC to transfer data, the MPU-6050 sensor with the objective of knowing its position and state placing it with rest of components inside, simultaneously a modification was made for the relay because the current that Arduino® should provide was higher than 20mA, which is why a transistor was used to make an adequate circuit.

Figure 1 Iron Scheme



Source: authors

3.3. Development

The following section explains the development to implement the proposed prototype. It was fundamental to use ADE 7763 and ACS714 current sensor for measurement processes, so as Arduino®'s algorithm. Arduino®'s SPI library offers four modes, and based on ADE 7763's (Analog Devices, 2016) datasheet, which stablishes SPI serial communication times, where the clock must start in a low level and MOSI can start in a high or low level, Arduino®'s mode one(1) was chosen.

The algorithm developed for this prototype stablishes bits order starting with the most significant bit, assigning data sending mode in mode one (1). Afterwards, SPI divisor clock was established to act over PIN 11 which activates ADE7763. Then, there is a pause in program to read bytes, and measured tension value is given. Finally, ADE7763 is deactivated with a pause in program. It is important to highlight that current, tension and energy measures need a measure calibration by a linear regression.

Regarding the accelerometer-gyroscope sensor, an algorithm was implemented on Arduino®'s Sketch which aims to detect that the electric iron is or is not in movement and if it is vertical or horizontal so one can take actions on the power off.

```
/*SENSOR*/
 SPI.setDataMode(SPI_MODE0);
 imu.read_all();
 g0= imu.gyroscope_data[0] ;
 g1= imu.gyroscope_data[1] ;
 g2= imu.gyroscope_data[2] ;
 a0= imu.accelerometer_data[0] ;
 a1= imu.accelerometer_data[1] ;
 a2= imu.accelerometer_data[2] ;
  if (g0>0 ) //|| AY>-21
      {            est="si";           }
    else if (g0<-2)
      {            est="si";        }
   else
     {             est="no";        }
    if (a0<-0.89)
      {            pos="horizontal";           }
    else if (g1<-0)
      {            pos="horizontal";        }
    else
      {            pos="vertical";        }
      Serial.print("   Movimiento = ");
      Serial.print(est);
      Serial.print(", Posicion = ");
      Serial.println(pos);
```

Ethernet Shield plaque is connected through a RJ45 wire with a PLC inside home electric network, likewise home's router is connected to another PLC with the objective of visualizing information inside the local network. Finally, the output signal of an Arduino®'s digital "pin" was modified so the relay's coil could be activated in order to have control over prototype, for this case it was necessary to implement a 2N2222 (Datasheetcatalog, 2016) transistor so the current was appropriate for actuator.

4. Tests and Results

Tests were developed at Universidad Distrital, initially changing tension and current levels in different time periods. Table 2 shows tension values measured with the network analyzer for network parameter register measures (PQA824) (HT Instruments, 2016) and the interval shown in Arduino®'s serial monitor initially showed dimensionless values, which is why a linear regression was made with Arduino®'s and PQA data for calibration.

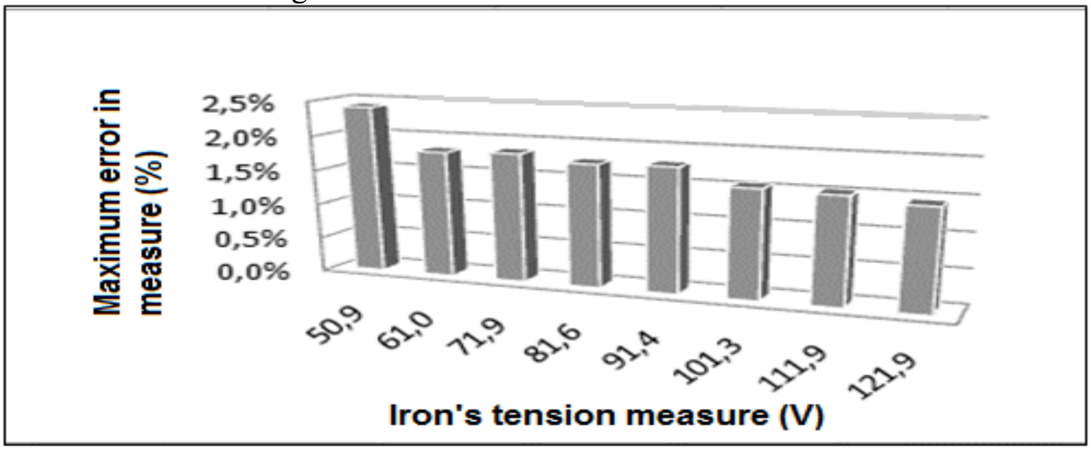
Table 2. Tension Values

Multimeter Tension	Arduino's Tension (V)			Error (%)		Max Error(%)
	Min	Max	Average	Min	Max	
50,9	49,66	51,14	50,40	2,4%	0,5%	2,4%
61,0	59,88	61,36	60,62	1,8%	0,6%	1,8%
71,9	71,22	73,28	72,25	1,0%	1,8%	1,8%
81,6	80,98	83,07	82,02	0,8%	1,8%	1,8%
91,4	90,88	93,00	91,94	0,5%	1,8%	1,8%
101,3	100,10	102,87	101,48	1,2%	1,5%	1,5%
111,9	110,97	113,60	112,28	0,8%	1,5%	1,5%
121,9	122,02	123,66	122,84	0,1%	1,4%	1,4%

Source: Authors, 2016.

Maximum perceptual error is 1,8% for values between 60V and 100V, in the other hand, with values higher tan 100V error decreases around 0,4%, which shows that for low tension values between 110V and 120V a maximum error of 1,5% is expected as shown in Figure 2.

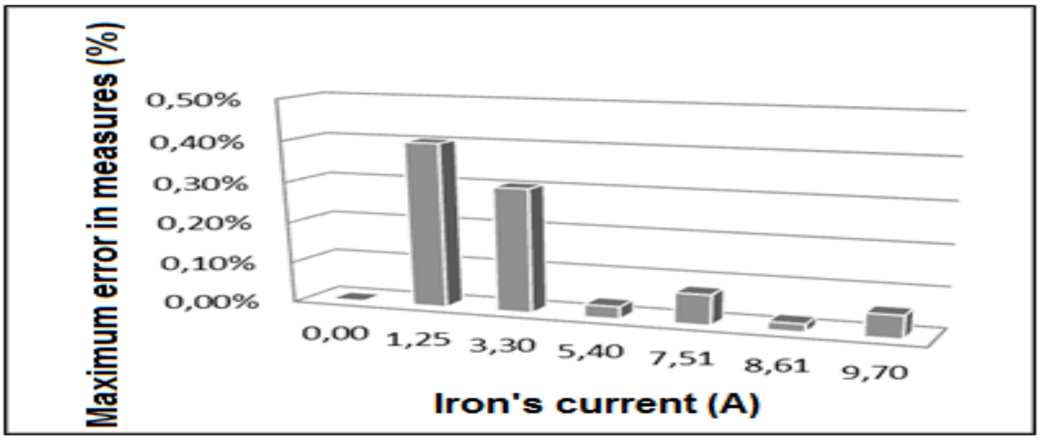
Figure 2. Tension measures maximum error



Source: Authors, 2016.

In Figure 3, measures highest and lowest error is 0, 9% and 0, 1% respectively for different current values, error do not beat 1% estimating that difference between Arduino's and multimeter measures was minimal. Results obtained are really similar to the ones shown by multimeter since its precision does not beat 1%.

Figure 3. Current Measures Error.



Source: Authors, 2016.

Since ADE 7763 measures energy and not power, it was necessary to develop energy measures at different times for calibration. In order to validate energy, energy had to increase at same time as PQA and Arduino®'s. To facilitate prototype's energy measures, two time intervals are observed, the first one PQA's energy values were 30Wh, and the values measured by Arduino® changed to 30.74Wh.

5. Conclusions

Protocols let the user monitor and supervise continuously the system with the objective of controlling its functioning through any device with internet access. This will let the user administrate this device more properly so it is energetically efficient thanks to benefits offered by powerline communication (PLC). Through an IP protocol used to monitor tension, current and energy parameters, electric iron's behavior becomes easier to control for the users who count with internet access, so control over the device can be taken from different places just by indicating the IP direction using the preferred internet explorer.

The developed prototype along with the proposed interphase allow interaction between residential user and web platform, because current, tension, energy consumption and an electric iron's price can be controlled from a local or external network through internet. This is a huge advantage comparing to other products offered in the market because they do not take into account the user for saving and use energy efficiently at home, this qualities make this interphase a fundamental tool to monitor energy consumption and control an electric iron.

Regarding monitoring, calibration of current, tension and energy of prototype was fundamental, in this case the calibrations were made with linear regressions, due to errors increasing significantly, likewise, it is necessary to develop many measurements in dragged on times because in short times measures error tends to grow. According to the developed tests, obtained values are trustable, which gives trust to the user so he can include this type of devices for home's energetic management in the close future.

As home is one of the most important places for people, this prototype offers as a plus, security by avoiding a fire caused by a plugged home device by a neglect, making it a more trustable product and increasing people lifestyle.

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