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AC home appliances in a DC home nanogrid

Electrodomésticos de CA en una nanored doméstica de CD

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Abstract

In order to satisfy needs at home, a way of incorporating renewable energy sources, storage devices and home appliances into a Direct Current Home Nanogrid, is shown. This technological option could increase the participation of the end users in the energy market. Currently, the electric system transition from Altern Current to Direct Current systems is easier due the availability of cheapest DC home appliances. Finally, we demonstrate that the energy saving when the DC home nanogridis used, it represents around of 15 %.

Energy democracy, Direct current, Efficiency

Resumen

Se muestra una manera de incorporar dentro de una Nanored Doméstica de Corriente Directa, fuentes de energía renovable, sistemas de almacenamiento de energía, así como electrodomésticos con el objetivo de satisfacer las necesidades de un hogar. La propuesta tecnológica pretende incrementar la participación del usuario final en la toma de decisiones dentro del mercado energético. La transición de un sistema eléctrico en base a Corriente Alterna hacia un sistema de Corriente Directa se facilita con la existencia de electrodomésticos de CD en el mercado local. Finalmente, se muestra una reducción en el consumo de energía alrededor del 15% con el uso de Corriente Directa.

Democracia energética, Corriente directa, Eficiencia

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Introduction

The incorporation of renewable energy sources (RES) into electric systems has promoted the emergence of distributed systems. This is a commitment in sustainable systems, with the aim of considerably reduce the emission of greenhouse gases in the electrical energy generation process. The fundamental concept for the development of distributed systems has been mainly focused on microgrids. A microgrid is performed by different sectors. Firstly, the energy generation sector, with a strong tendency to incorporate RES (wind and photovoltaic power plants). The next is the distribution sector that is composed of the wiring that feeds the load sector. In order to ensure the reliability and stability of the microgrid, the energy management sector (EMS) is able to provide information about generation and consumption of the energy. The advantage of the distributed systems lies in avoid the energy loss due the transmission of energy over long distances as well as the ease of integrating RES, which generate energy close to the end users. However, distributed systems operate with a similar dynamic to the traditional centralized systems, for which the flow of energy originates from large renewable energy parks or power plants to end users. On the other hand, RES has promoted the development of awareness in members of the society who are concerned about phenomena such as global warming or climate change.

Currently, it is sought to achieve increasingly efficient electrical systems, for which it has been incurred in the development of systems based on Direct Current (DC). These kinds of systems have proven to be greater energy efficiency, with lower losses and better performance in a simple and an easier way with respect to systems based on Alternating Current (AC). The growth of DC systems has been limited due to a wide dominance of AC systems in the energy market, to the extent that there is a lack of DC appliances (Moussa, Jebali-Ben Ghorbal, & Slama-Belkhodja, 2018). This is a critical factor for the migration to DC systems by the end user.

It is intended that the DC home nanogrids (DCHN's) are established as a technological development, involving renewable energy sources and energy storage systems, which in turn provides greater opportunity for end user participation in the energy market.

With the technological changes driven by RES and new energy storage system (ESS), it is intended to develop an electrical system aimed at the domestic sector, which incorporates RES and ESS to meet needs and diminish dependence on the public grid. In principle, the characteristics that such a system must meet is to be simple and easy, attractive and viable for the end user from the economic and efficiency aspects.

This paper presents the technological development of a DCHN, oriented to satisfy the daily needs of a house with the incorporation of RES and ESS. It shows the possibility of using high efficiency household appliances initially designed to operate in AC, working inside a DCNH with slight, or without, modifications.

This article is structured as follows: in the *General configuration of nanogrid, an* overview of the sectors that make up the nanogrid is described. In the *Voltage level* section, various reported voltage levels are shown. The *DCHN Configuration section* describes the nanogrid developed in this research. The *Appliance Selection section* establishes criteria and it mentions the appliances used. The section *Appliance behavior within the DCHN* presents experimental readings. It continues with the *Results* section followed by *Acknowledgments* and finally the *Conclusions* section.

General configuration of the nanogrid

Recently, the design of electrical systems has focused on their optimization, with the aim of achieving more efficient systems. In order to reduce energy losses, high efficiency appliances are incorporated, whose power electronics employed, gives them a non-linear behavior. The nature of these loads represents a great challenge for the stability of electrical systems.

Within the nanogrid, like the microgrids, sectors with specific functions are identified. The first sector that we will describe is the energy generation sector. In this sector is carried out the generation of energy with a predisposition towards renewable energy sources. Nowadays, the energy storage sector has taken great importance, mainly due to the impulse in the development and commercialization of electric cars.

This has allowed a drastic reduction in price, weight and size of batteries. Therefore, the integration of energy storage devices within a DCHN is feasible.

The distribution sector consists of the wiring through which energy is transmitted to the load sector. In the power transmission processes such as the Joule effect become very relevant for the sizing and design of the wiring. Regarding the load sector, this is characterized by the presence of high efficiency appliances with a non-linear behavior. The electrical protection system will be occup of limiting damages and avoiding the propagation of undesired phenomena such as short circuit or overload within the system. In a condition of a gradual discharge inside the storage sector that compromises the stability of the system and/or the useful life of the batteries, it can be taken as a function of the protection systems, it is to emphasize that this condition corresponds to a function of the EMS. In this sector, the data collection of the energy generation and consumption process is carried out; the parameters for an optimal operation of the system are established. For this sector is visualized a wide area of study to be carried out for future research linked to the concept of "Smart Home".

Voltage level

Among the typical applications of DC electrical systems can be mentioned mainly the automotive sector. In which the voltage level range between 12 and 24 VDC, being able to reach values of 48 VDC. In industrial applications, the usual voltages are considered high voltage levels such as 380 VDC. Historically, we back to the firsts electrical systems developed by Thomas Edison which used DC (AILee & Tschudi, 2012). The voltage level used in those systems corresponded to a value of 100 VDC (Barazarte, 2013). The selection of the operating voltage level in the DCHN is a critical step. Currently, DC nanogrids with different voltage levels have been proposed, many of them based on automotive applications involving low voltages equivalent to 12VDC.

These incorporate appliances designed for those voltage levels. In addition, the configurations of a DC nanogrid have been diversified, coming to establish buses with different voltage levels according to the appliances, with a voltage range from 12, 24, 48, 380 VDC. Each of these buses is interconnected between them by means of converters whose function is to stabilize the voltage level in the buses.

DCHN Configuration

The proposed configuration in this research is shown in Fig. 1. The energy generation sector of the DCHN is performed by 5 photovoltaic panels with a power of 250 watts each. Our energy storage sector is made up by a battery set of 10 batteries, it should be noted that this battery set is taken from an electric vehicle. The nominal voltage of each battery corresponds to 12 VDC, which establishes a nominal voltage for the battery set of 120 VDC, as well as for the distribution and load sectors (Cordova-Fajardo & Tututi Hernández, 2019). Each photovoltaic panel has the capacity to supply power to a pair of batteries with a voltage of 24 VDC. The distribution sector is formed by a distribution bus, for which, it is used the same wiring intended for AC systems. This makes easy to implement a DCHN in a typical AC home. This includes the contacts, switches, plugs and other accessories.

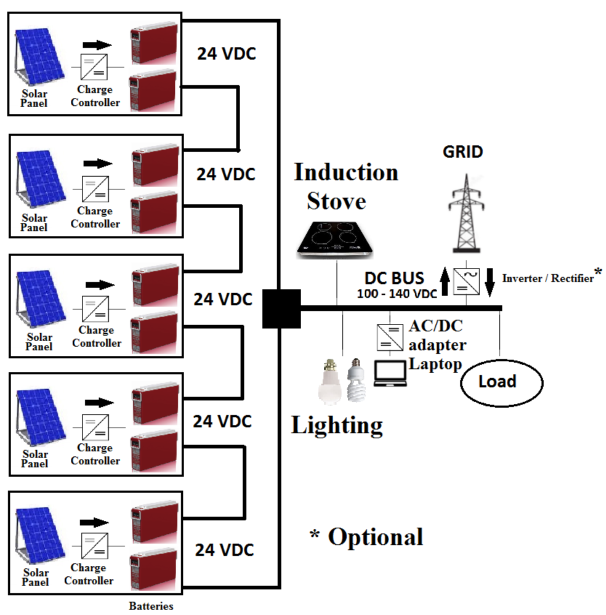

Figure 1 Proposed configuration for CDHN
Source: (Cordova-Fajardo & Tututi Hernández, 2019)

Selection of Appliances

In this section, we focus on the search and selection of appliances available in the local market to incorporate them into the DCHN. The process of converting electrical energy into useful work, in other words, the consumption of energy to meet our daily needs within the home, is carried out by the appliances located in our load sector. In this regard, we face the challenge of limited availability within the local market of appliances designed to operate on DC.

For the power conversion process, high efficiency appliances based on switched power supplies have been developed. On the other hand, the first phase of operation of a switching power supply consists of the rectification or AC/DC conversion process for the operation of its internal components. This phase is key in the selection criteria of most household appliances, so it facilitates its incorporation into a DCHN without or with slight adaptations. Taking into account the process of cooking food within the home, it is identified that the induction cooker satisfies the selection criteria for incorporation. The technical data of the selected induction stove corresponds to a power of 3600 watts, 120 VAC, 60 Hz and 4 burners with trade mark Sisolar, as it is shown in Figure 2. The incorporation of the induction stove is carried out without any modification and with the use of accessories such as plugs and usual contacts in AC systems.

For the lighting sector, LED lamps are incorporated, whose operation of its internal components is carried out with DC. Within the local market, the following LED lamp is selected with the following technical data such as a power of 30 watts, a voltage of 120 VAC and a frequency of 60 Hz.

Figure 2 Induction stove into DCHN
Source: (Cordova-Fajardo & Tututi Hernández)

It should be noted that its incorporation into the DCHN is carried out without any modification. The selected LED lamp is shown in Figure 3.

Figure 3 LED lamp working at 120 VCD
Source: (Cordova-Fajardo & Tututi Hernández)

Finally, a blender is incorporated into the DCHN in order to cover the need for food preparation. The technical data of the blender corresponds to an operating voltage of 120 VAC, with a power of 600 watts at a frequency of 60 Hz, which is shown in Figure 4.

The appliances aforementioned have been selected to be incorporated into the DCHN above described. The following section describes their behavior within the DCHN.

Behavior of Appliances within DCHN

This section describes the behavior of the appliances selected for incorporation into the DCHN. The energy consumption data collected for each appliance is presented in two stages.

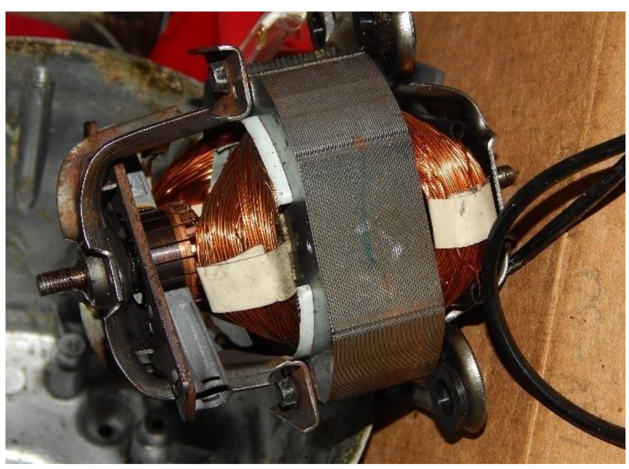

Figure 4 Blender motor
Source: (Cordova-Fajardo & Tututi Hernández)

In the first stage, we obtain the measurement of the electric current at each appliance in the AC system with 120 VAC. At the second stage, we perform the measurements of the electric current, but now for the DCHN with nominal voltage of 120 VCD. In Table 1, it is shown the results for the electric current in each appliance.

Home appliance	CA	CD
Induction stove	10.8 A	9.1 A
Blender	2.4 A	2.7 A
LED lamp	450mA	380 mA

Table 1 Consumption of appliances in AC and DC regimens
Source: (Cordova-Fajardo & Tututi Hernández)

Let us stress that the electric accessories, such as plugs, switches and contacts were equally used in AC as in DC in the DCHN.

Results

The measurements for the induction stove in both AC and DC were obtained at the maximal power. However, this condition rarely occurs, and is of relatively short interval of time. That is to say, it happens when the end user wishes to quickly warm their meals. If the time interval of warming is large enough, it could burn the meal due to great quantity of energy supplied.

This condition could be demanding for the DCHN, for which results important its analysis. The resulting measurement of the electrical current consumption of the stove operating in DC within the DCHN is 15.74 % less with respect to system in AC. As far as the corresponding measurements in the blend is concerned, these results 12.5 % higher operating in the DCHN than in the AC system. For the LED lamp, we observed a diminishing of 15.55 % when the lamp operates in the DCHN.

Acknowledgements

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Conclusions

The participation of different sectors (society, state, government or private initiative) involved in the energy market will favor the transition to sustainable systems.

The development and reduction of costs of energy storage devices will allow changes in the dynamics of the electric systems. These changes go from technical to economic aspects. The evolution of proposals such as DCHN than involve the use of sources of renewable energies and energy storage devices have increased the participation of end users and increased the awareness respect to their energy consumption style. Experimental data show an average decrease around of 15 % in the consumption of energy in a DCHN. Which is due to the reduction of stages in the energy conversion AC/DC. The generation and consumption of energy *in situ* avoids the transmission of energy at large distances with subsequent energy losses. Finally, in order to carry out the transition from AC to DC systems, it is necessary to implement technical standards to regulate the use of home appliances for to be manageable easily in both AC and DC. It is also necessary to define the level of the intensity of the voltage to operate a DCHN, to fix it as a standard.

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