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Importance of the Power-Electronic on Integration Processes Using Renewable Energies

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Power Electronics Technology has significantly evolved over the last years. As a result of tremendous developments in the semiconductor industry, the number of industrial applications in which high-performance devices are used, has been increasing. Nowadays, this technology plays an important role in the integration process of novelty renewable energy applications, the control of a system including different types of energies (e.g. thermal and electrical) can be a good example.
Recently, the employment of a system based on the integration process technique, known as PMHI (Power, Mass and Heat Integration), has been gaining interest. In PMHI system, operative parameters are controlled by electronic devices.
In this work, the electric parameters in a PMHI system controlled by power electronic devices are verified. The verification of these parameters is important for the process operation due to even a small variation in any electric parameter can cause a significant change in operation flows accuracy. A study case where commercial power electronic devices and a PV cell are utilized to provide the electrical energy required to build up a PMHI system, is presented. Electric parameters in the system are compared for two different cases of electric energy supplied: Energy generated through the PV Cell and Energy obtained from electrical network. Even though, theoretically, no differences should be expected from both cases, experimental results show the opposite.

1. Introduction

Integration process techniques demand an incorporation of different types of disciplines and a constant technology updating. Before this situation, the Power Electronics Technology represents a great solution to improve the operation of industrial processes and the power quality of electrical energy. Recently, a group of researchers have focused their efforts in the development of research works where power electronic devices operate along with integration process techniques as in cooling and pumping systems (Martinez et al., 2010); in both cases, the power is the common element between integration process techniques and power electronics technologies.
In this way, the incorporation of power on integration processes represents an attractive application for power electronic devices, in which these types of devices would support the interchange between different sources of energy ensuring the power quality required for any equipment inside the integration processes in order to maintain unaltered operation conditions.

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In the next paragraphs, it is exposed the importance of Power Electronics Technology, so that incorporation of renewable energy technologies in industrial processes would be feasible.

2. Power Electronics Technology

At the end of the 60's, it was developed the first VAR compensator device which have a considerable economic cost. The cost of that device was a good way to exemplify that, at the moment, the utilization of Power Electronics Technology was out of reach for more industry applications. However, the ever increasing development in the semiconductors field, applied to the power electronics, caused the emerging of new components and devices at lower cost and with more capabilities. This technological revolution has an immediate repercussion in the industrial scope.

On the other hand, renewable technologies have had a remarkable penetration in power systems (Eskander and Aziza,1997; Betka and Moussi, 2004), causing that actual power grids become dependent and vulnerable to the variability of the energy generated by this type of resource. In that sense, power converters provide a crucial function in the performance of the overall electric system when they are used as links between generators of variable energy and the power system or electric loads. Power converter must be capable of supplied voltages with controllable magnitude and frequency, besides a high power quality. Commercially, as the power quality exhibit by the power converter increases so does it the price. Thus, generally a common commercially available power converter operates with a low level of power quality, generating power signals with a considerable quantity of harmonic components which results in higher losses, insulation damage, and an inadequate operation of the whole industrial process.

In this paper, it is exposed that by using the appropriate modulation techniques it is possible to propose the Power Electronics Technology as a good alternative to incorporate the power generated by renewable energy sources, ensuring a high power quality and maintaining unaltered the industrial process.

3. Power Electronics Technology on Renewable Energies

3.1 PMHI system and Renewable Energy

There are some industrial processes where Integration Process Techniques have been applied to achieve a minimum quantity of electrical energy, thermal energy and water consumption. This process integration has received the name Power, Mass and Heat Integration System (PMHI). Since these types of systems are driven by a water pump supplied with electrical energy, it has been proposed the utilization of renewable resources. In a previous work, (Martinez et al., 2012); it has been demonstrated the existing alternatives to integrate the PMHI system with the renewable energy resource; in Figure 1, it can be observed two possible alternatives of connection between the power inverter and the PMHI system.

3.2 Power Electronics Technology and Electric Parameters

As can be seen from Figure 1, the power inverter plays a fundamental role in the overall process, supplying all the electrical signals (voltages, currents, etc.) to the PMHI system according to national and international regulations, in order to maintain the pumping system within and adequate performance. In this paper, Pulse Width Modulation technique (PWM), Figure 2, along with the Selective Harmonic Elimination Modulation technique (SHEM) is utilized to generate a voltage waveform with the required magnitude and frequency to accomplish power factor correction in the system and power quality improvement at the power inverter output terminals.

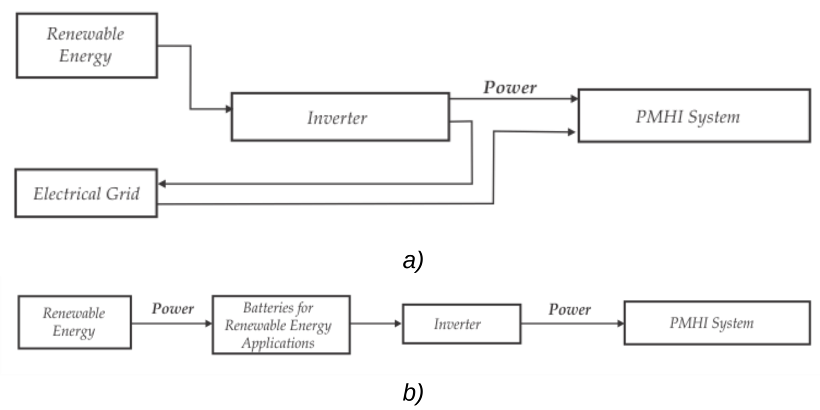

Figure 1. a) Power generated by renewable energy along with supply from the electric grid; b) power is generated by renewable energy and a set of batteries supply the power to the PMHI system

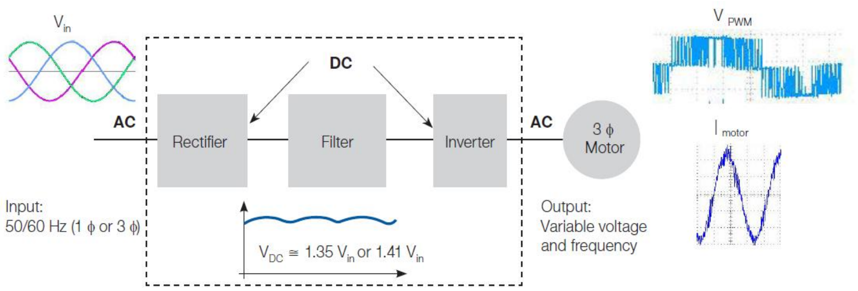

Figure 2. Pulse Width Modulation technique.

When power inverters are used in applications related to linking electrical systems and renewable energy sources, these devices must ensure a high power quality of the energy supplied to electrical loads. In this particular case, the SHEM modulation technique is implemented with that purpose.

4. Study Case

In order to verify the effectiveness of the proposed application, some experimental tests were carried out in a prototype laboratory-scaled system in the DICIS of Guanajuato University, México. For this study case a prototype integrated by a 1 HP water pump connected to a pair of mono-crystalline photo-voltaic panels of 140 Wp through a 12 V deep cycle battery with 104 ampere-hour (A-h) of capacity.

As was stated before, it is necessary to set the right values at which electric parameters need to be corrected. For the Power Factor, the ratio between active and reactive power, it is desirable to keep it around unity to ensure the highest transfer of active power; Figure 3 shows a comparison between the power factor at the pump input terminals when the battery-power inverter system and the electrical grid are utilized.

On the other hand, harmonic pollution in power systems both in voltage as current waveforms is a topic that, lately, has gained a lot of interest. Harmonic distortion is related to the disturbance of voltage or current signals from their sinusoidal waveform, and this distortion is due to the addition of signals with a frequency that is a multiple of the fundamental component's frequency.

Figure 4 presents how the value of Power Factor is being modified towards unity, through the operation of an Advanced Static Vars Compensator (ASVC).

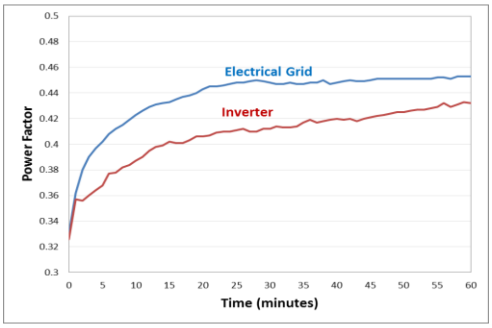

Figure 3. Power Factor: Electrical Grid vs Inverter; for Case Study

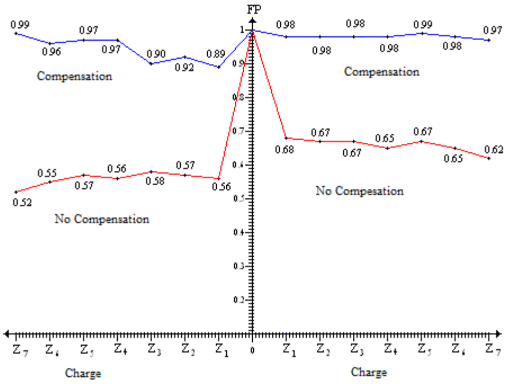

Figure 4: Power Factor Correction.

An index that is used to represent the content of distortion in a signal, is the Total Harmonic Distortion (THD), that can be calculated by,

$$THD = \sqrt{\sum_{h=2}^{\infty}\left(\frac{A_h}{A_1}\right)^2} \tag{1}$$

Where:

A_h= are the rms values of the non-fundamental harmonic components.

A_1= is the rms value of the fundamental component.

In any system involving switching elements, the THD becomes a parameter to take into account due to the rise in temperature produced in electric equipment with iron cores. In water pumps the increase in temperature can reach a 5 %, affecting the efficiency directly and reducing the machine's life span (Fouladgar and Chauveau, 2005) (Hilderbrand and Roehrdanz, 2001).

In Table 1, IEEE Std. 519 recommended values concerning maximum harmonic distortion percentages for systems with voltage levels less than 69 kV, are presented.

Table 1: THD levels for power systems ≤ 69 kV (IEEE Std. 519).

Voltage harmonics	
Even components	3 %
Odd components	3 %
$THD_{voltage}$	5 %

For the study case using the commercial power inverter the THD is above 20 %, so that is out of the limits imposed by IEEE STd. 519, Table 1. In Figure 6, it is possible to appreciate the voltage and current waveforms and is clear that both signals have a substantial distortion.
Applying the modulation techniques PWM-SHEM it is possible to synthesized better voltage waveforms, as can be seen in Figure 7.

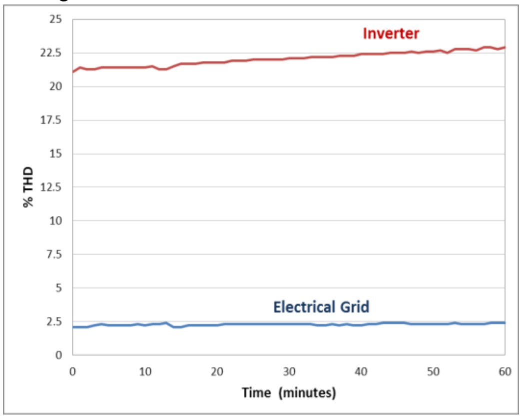

Figure 5: % THD from study case

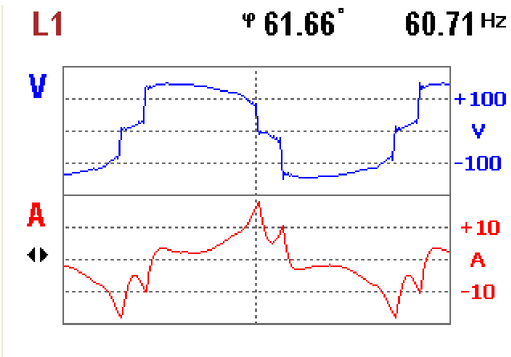

Figure 6: Waveform obtained from the commercial inverter.

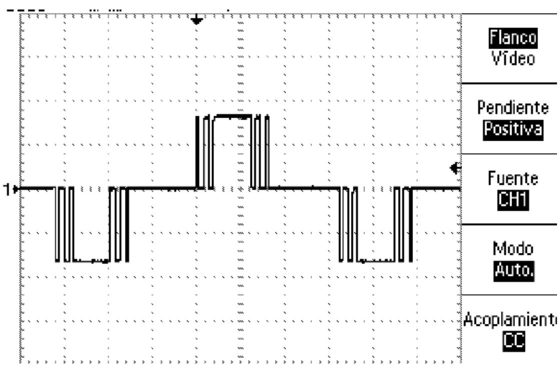

Figure 7: Waveform obtained with PWM technique

5. Conclusions

Through the results obtained from the study case analyzed, it is plain to see the immense field of opportunities that represents the utilization of power electronic devices in industrial process where electric energy is generated by renewable technologies. It is worth noting that, without power electronic devices, the power quality of the energy injected in the electrical system would not accomplish the international regulations. Besides, power electronic devices can control the industrial process main operative variables as temperature, water flow, etc., and guarantees the operation of renewable energy technologies in the integration process, as could be verified in the study case presented.

Acknowledgement

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