Producing electricitys with different technologies engineering essay

Engineering

Today, we are producing electricity with different technologies, classic and renewable energies. However, a great part of it is still done using fossil fuels that cause terrestrial emission of carbon dioxide which, as all people know, produces earth overheating by the greenhouse effect. The greenhouse effect is a process that results in an elevation of the average surface temperature. The solar radiation is absorbed by the atmospheric gases, and is re-radiated in all directions. Part of this re-radiation is accumulated between the surface and the atmosphere and makes this increase of the temperatures. However, by using fossil fuels we are intensifying the concentration of some atmospheric gases, such as CO2, causing global warming. To avoid it, Europe has proposed different objectives to use renewable energies, such as wind energy. Actually, the wind energy is not a new resource. The humans have been using the wind energy for thousands of years. We have transformed the resource into other types of mechanical energy more useful. The major improvement was to be able to generate electricity with wind turbines and connect them directly to the network. Nowadays, the wind turbines have three rotor blades in a horizontal axis, a nacelle where are the rotor, gears and a generator. The rotor is positioned perpendicularly of the tower axis in the direction of the wind. There are some dates in the history that we should know, because of the importance in this field. Albert Betz has developed a theory to design the optimal geometry of rotor blades and measure the maximum performance of a wind turbine in 1920 and 1926 known as the " Betz limit". Professor Ulrich Hütter has made an experimental system to the construction of blades for the wind turbines in 1950 with modern aerodynamics fibre optics technology. After that, Poul la Cour invented a wind turbine which was able to generate direct current. Johannes Juul, one of his students developed the " Danish Concept" in 1958 in order to explain how to feed alternating current (ac) to the grid. This was an important point in the development of the wind turbines. Today, almost half of all operate according to this idea. In the 1980's, thanks to the state help, in Denmark it was developed turbines with a low power capacity, from 20 kW to 100 kW. They were installed in farms, in the coast or in small villages in order to have a distributed power generation. Also, with the excess of power generated, it was fed to the electrical grid. Today, we have experienced an important technical development and thanks also to campaigns to raise public awareness the wind energy has increased rapidly, in land and offshore. We can say that nowadays wind power has become in a mature technology to generate electricity, and for several countries it has a high percentage of the global power generation. It is possible to see this increase in the power capacity in several countries, and also plans to future improvements. In the last fifteen years, each year the growth average rates was about 28% and the commercial wind power installations in about eighty countries at the end of the year 2011 was about 240 GW. This speed growth has no precedents. Also, it is important to say that there are about twenty two countries that have installed more than 1. 000 MW.

1. 3. 1. USE OF WIND ENERGY.

In Europe, the two countries which have more wind energy are Germany and Spain. In the next figure we can see the new power installed in each region, each year. While Europe shows in the last years a constant new power installations, Asia is each year installing around 20. 000 Mw new in wind energy. Figure 1. 1. Annual installed capacity by Region. If we compare the year 2012 with the previous one, almost every European country have a bigger growth in the first half of this year. The only tow countries that have shown a decrease in the new installed capacity was Spain and Portugal due to the fact that the governments are reducing their budget in infrastructure investment. If we see the capacity of each country, the biggest market in Europe is still Germany with capacity installed in the first part of 2012 of 941 MW and a total of 30. 016 MW. Also Spain has news installation of 414 MW with a total of 22. 087 MW, Italy new installations of 490 MW, 7. 280 MW total, France with 650 MW new, 7. 182 MW in total, the United Kingdom with a new capacity of 822 MW and a total of 6. 480 MW and Portugal 19 MW news, 4. 398 MW total. Furthermore, the countries of Eastern Europe have the best rates of growth. For example, Romania with a 33% growth (274 MW added), Poland with a 32% (527 MW added), Ukraine with a 64% (37 MW added) and Latvia with a 64% (20 MW added). In the next figure, we can see the percentage of wind energy (by 2010) generated in Europe. Figure 1. 2. Percentage of use if wind energy 2010 (eurostat). If we study the rest of the world, China is another time in 2012 the largest wind market with a high difference. China has added 5. 4 GW the first six months of 2012, and they have the 32% of thw world market for new wind turbines. Nevertheless, the growth was significantly less than in 2011, when it was added a new capacity of 8 GW. By June 2012, China had a total installed capacity of around 67. 7 GW. By far, China is the biggest wind generator, and it will continue in the next future being the number producer and installer, but at a lower speed than other years. Also, India added the impressive capacity of 1. 471 MW, a similar amount like in the first of 2011. However, the future of the Indian market is not clear due to the fact that the payments for wind generators in some parts of the country are changing and the current decisions to reduce some support plans. The United States of America added a new capacity of 2. 883 MW in the first half of 2012, about 28% more than in the same period in 2011. Also in this market there are some uncertainties because of the unclear situation about the future of the Production Tax Credit. There are some companies that have already started to fire people, and the future for the US wind companies will be dangerous unless they develop a new support plan. If we study the Canadian market, they have installed around 246 MW in the first half of 2012, less than in the previous period in 2011. In the next figure we can see the new power installations in the world, and the total power generated. Table 1. 1. Wind power installations. We can see the total power installations in the last years in the next figure. In the following years, it is expected to show the same tendency in the entire world. Each year the wind power is more important in our society. Figure 1. 3. Global cumulative installed wind capacity (1996- 2011).

2. STRUCTURE OF A MODERN WIND TURBINE.

A modern wind turbine is usually composed by the next parts: To fix the structure in the ground it is used the foundation. Depending on the ground where the wind turbine is installed, it is used a pile or flat foundation, in order to guarantee the stability of the turbine. The tower construction has to resist the weight of the nacelle and the rotor blades and also absorb the static loads and torques caused by the changes in the wind speed. The tower is usually made of a tubular construction of concrete or steel. An alternative to this is the lattice tower form. Of course, an important part of a wind turbine is the rotor. It is the component used to transform the wind energy in a mechanical rotary power. In order to do this, the rotor has two or three rotor blades. Nowadays, almost all the wind turbines have the three-blade rotor with horizontal axis. The blades are usually made of glass-fibre or carbon-fibre reinforced plastics (GRP, CFRP). The blade profile is similar to an aeroplane wing, because they use the same principle of lift: the air generates a higher pressure on the lower side of the wing and in the upper side generates a pull. Because of this two forces, the rotor have a rotary movement. Another part of the wind turbine is the nacelle. It holds all the machines in the turbine. Between the tower and the nacelle, there are some bearing is order to connect both parts. This is because of the fact that the nacelle needs to be able to rotate in order to follow the wind direction. The build-up of the nacelle is decided and designed to make the necessary space for the drive train components (rotor shaft with bearings, transmission, generator, coupling and brake). In it, there is also the gearbox that converts the slow rotor motion of 18-50 rpm into the speed which the generator requires. Due to the fact that the wind speed can change, the gearbox has several steps in order to adapt the low rotor speeds with the needs of the generator. Sometimes the gearbox is not required, but we have to use a specially developed multi-pole ring generator. For applications where high power turbines are needed, the doubly-fed generators are usually used (for more information, go to section number 3). As it is going to be explained, the rotor speed can change if the wind varies, unlike the asynchronous generators. It will be used also normal synchronous generators, but we need transformers in order to connect them to the grid due to the fixed speed behaviour. The need of requiring complicated control systems is a disadvantage, but the higher efficiency and better grid compatibility make a difference in this generator. The connexion used between the main shaft and the transmission is a rigid one, because of the high torque that the turbines develop. There are also brakes that depend on the control mechanism for the blades and the type used. Also, it is needed electronic equipment. It is composed of the generator, the system to connect the grid to the wind turbine, like rectifiers or inverters (or both), and several sensors. We can have sensors in order to measure temperature, wind direction and speed and many other variables that the turbine needs in order to have a right control and monitoring. Finally, the wind turbine has other components to follow the wind direction, for cooling, heating and lightning protection, as well as lifting gear and fire extinguishing equipment.

2. 1. WIND TURBINE GENERATORS.

Obviously, the most important part of a wind turbine is the electric generator and based on it are designed the rest of the elements in the wind turbine. The AC generators have several advantages over the Dc machines, such as a lower weight (which implies a smaller nacelle), lower maintenance costs and they have a higher availability in all the electrical machines markets. If we use synchronous generators it is necessary to maintain a constant rotor speed to generate a constant power. Because of that, if the winds change, it is caused significant mechanical stress on the transmission system and oscillations in the mechanical power. Thus, in order to connect the generator to the network it is usually used a power electronic converter and then we can allow the rotor speed to vary in a small range. In the other hand, if we use an asynchronous generator, we can take advantage of the small wind variations because this motor can have small speed variations maintaining the output frequency constant. In the next point it is going to be examined the two great families of generators, among which are several variants.

2. 1. 1. SYNCHRONOUS GENERATORS.

In these generators the rotor speed must be equal to the synchronous stator speed, because the voltage and current frequency depend on the rotational speed. If the rotor speed is changed then the outputs will be different to 50 Hz. Because of the fact that the wind speed can change and the need to have a synchronous speed in the rotor, these generators are connected to the electric grid using a power electronic converter as an intermediary between the generator and the grid. The different types of synchronous generators are: Wound rotor generators. Permanent magnet generators.

2. 1. 2. ASYNCHRONOUS GENERATORS.

These generators have the main advantage that even if the wind speed has small variations, we can maintain constant frequency in its outputs terminals. However, these machines need to consume reactive power in all kind of operation, and that is why it is required reactive compensation. In the figure 2. 1, we can see the consumption of reactive power depending on the active power generated. As a solution to compensate this fact, It can be placed some capacitor banks with variable steps, or other solution could be a reactive control through a static compensator filters composed of thyristor or IGBT assets, but this will result in a higher cost. Figure 2. 1. Performance, power factor and reactive consumption depending on the load. We have to keep in mind that when we connect an asynchronous generator to the network it involves high current peaks, which may trigger the protection. In order to solve this problem, it is used soft starter to start these machines in some applications, where this soft starter uses a voltage that is not the nominal, is a bit lower in order to have small current peaks. We must take the caution to disconnect the capacitors in this process, because these provide significant harmonic content. One disadvantage that has the asynchronous generator is the need to use a gearbox. This introduces mechanical losses in the turbine, rising cost of maintenance, cost overruns on the structure and increased noise pollution. Now, is presented the different wind turbines technologies with constant speed and variable speed. Constant speed wind turbines: Wound rotor synchronous generator. Permanent magnet generator. Variable speed wind turbines: Asynchronous generator with slip control by rotor resistance. Asynchronous generator with slip control with energy recovery. Doubly fed generator (DFIG). Squirrel cage asynchronous generator.

3. DOUBLE FED ASYNCHRONOUS GENERATOR.

Even though these machines and their principles of operation have been known since years ago, it is only a few years since they are widely used. As it is said in the previous point, the electric generation with wind turbines is the reason why now these machines have been increased their importance. Doubly-fed electric machines are electric machines with stator and rotor windings, in order to feed them with sinusoidal currents. Doubly-fed induction generators (DFIGs) are one of the most common types of electrical machine used to produce electricity in wind turbines, because of the fact that they have some advantages over other types of generators when used in this kind of application. First of all, when we want to use this generator in wind turbines is it is allowed to keep constant the amplitude and frequency value of their output voltages, even if the speed of the wind changes the speed rotation of the machine. Because of this, doubly-fed induction generators are usually directly connected to the electrical grid and remain synchronized at all times with the power network. They have also other advantages such as the ability to control the power factor (for example, to maintain the power factor at unity) and having a moderate size of power electronic device in the wind turbine.

3. 1. MACHINE OPERATION.

It can be set up a three-phase induction machine with a wound rotor as a doubly-fed induction motor. The machine works like a synchronous machine in which the rotor is going to rotate at the synchronous speed. But in this case, the synchronous speed can be changed by using different currents. We can modify the current frequency fed to the rotor, frotor., and then the rotor can rotate in different speeds. Also, if we want to set it up as a doubly-fed induction generator, the mechanical power at the machine shaft is converted into electrical power supplied to the ac power network via both the stator and rotor windings. As it was explained before, the machine works like a synchronous generator whose synchronous speed (the speed at which the generator shaft must rotate to generate power at the ac power network frequency, fretwork) can be changed by modifying the current frequency fed into the wound rotor. In a conventional three-phase synchronous generator, the process to obtain electricity is the following. When we have an external source of mechanical power makes the rotor of the generator rotate, the dc current fed into the generator rotor makes a static magnetic field. As the rotor is moving by the source, the magnetic field rotates at the same speed (nrotor) as the rotor. As a result, we have in the stator windings a continually changing magnetic flux because of the rotor magnetic field that will induce an alternating voltage across the stator windings. The mechanical power applied to the generator shaft by the prime mover is thus converted to electrical power that is available at the stator windings. In synchronous induction generators, the relationship between the frequency of the ac voltages induced across the stator windings of the generator (fstator) and the rotor speed nrotor is expressed using the following equation. Equation 3. 1. Where fstator is expressed in hertz (Hz), nrotor is the speed of the generator rotor expressed in rotations per minute (rev/min) and Ppoles is the number of pares of poles in the induction generator per phase. Using Equation3. 1, it is esay to know that, when nrotor is equal to the generator synchronous speed (ns), the frequency of the ac voltages induced in the stator windings of the generator is equal to the frequency of the ac power network, or fnetwork. Nevertheless the magnetic field created in the rotor of a doubly-fed induction generator is not static because it is created using three-phase ac current instead of dc current. However, we can apply the same operating principles in a doubly-fed induction generator as in a conventional synchronous induction generator. The only difference is that the magnetic field created in the rotor now rotates at a speed nΦ, rotor proportional to the frequency of the ac currents fed into the generator rotor windings. This means that the rotating magnetic field passing through the generator stator windings not only rotates due to the rotation of the generator rotor, but also due to the rotational effect produced by the ac currents fed into the rotor windings. Thus, in a doubly-fed induction generator, the frequency of the alternating voltage induced across the stator windings are determined by the speed of the rotating magnetic field in the stator windings (nΦ, stator). And this rotating magnetic field is caused by the rotation speed of the rotor and the frequency of the currents fed into the rotor windings (frotor). If we think in how the doubly-fed induction generator works, it can be proved that when the magnetic field at the rotor (nΦ, rotor, proportional to frotor) and the rotor itself have the same direction with a speed n rotor, then the resultant magnetic field is the add of both. This is shown in Figure 3. 1. The frequency of the voltages induced across the stator windings of the generator can thus be calculated using the following equation: Equation 3. 2Where frotor is the frequency of the ac currents fed into the doubly-fed induction generator rotor windings, expressed in hertz (Hz). In the other hand, when the magnetic field at the rotor and the rotor itself rotate in opposite directions, nrotor and the speed of the rotor magnetic field subtract from each other. This is shown also in the figure 3. 1. Thus, fstator can be calculated using the following equation: Equation 3. 3Figure 3. 1. Interaction between the rotor speed and the frequency of the rotating magnetic field created in the rotor windings of a doubly- fed induction generator. In other words, the frequency of the ac voltages and currents produced in the stator windings of a doubly-fed induction generator is proportional to the speed of the rotating magnetic field at the stator (nΦ, stator). This field depends on the rotor speed, n rotor (resulting from the mechanical power at the rotor shaft) and the frequency of the ac currents fed into the machine rotor. Depending on the direction of both, nΦ, stator is the addition or the subtraction.

3. 2. FIXED-FREQUENCY VOLTAGES GENERATION.

Now that it has been explained the main operation of the machine, it can be explained the main reason for a doubly-fed induction generator. When we have the wind turbine generator connected to the network, it is necessary that the three-phase voltage that is generated in the stator remains constant, and equal to the value of the electrical grid, or fnetwork , despite of the rotor speed variations caused by the mechanical power source. In other words, even if the wind causes a change in the rotor speed, the output voltage must have the same value and frequency. In order to reach this condition, we have to measure in real time the value of the nrotor and be able to adapt and generate the currents fed in the rotor windings at a variable frequency. Thus, when we have a speed variation because of a fluctuation in the mechanical power source, we have to change the frequency of the currents fed to the rotor. The frequency of the ac currents that need to be fed rotor windings to maintain fstator at the same value as the frequency fnetwork depends, as it has been explained before, on the rotation speed of the generator rotor, and can be calculated using the next equation: Equation 3. 4Where frotor is the frequency of the ac currents that need to be fed into the doubly-fed induction generator rotor windings for fstator to be equal to fnetwork , expressed in hertz (Hz). Using Equation 3. 4, it is possible to calculate that, if the rotor speed is the nominal synchronous speed ns, the frequency of the currents that should be fed are equal to 0 Hz, this is a dc current. Thus, the machine will operate in this case as a conventional three-phase synchronous machine. However, when the rotor speed decreases under the nominal synchronous speed, we have to increase in the positive polarity the frequency of the ac currents that are fed into the rotor windings. The positive polarity of the frequency f rotor refers to the fact that the phase sequence of the three-phase ac currents fed into the rotor must make the rotor magnetic field rotate in the same direction as the generator rotor, as is illustrated in Figure 3. 1 a. In the other hand, if the rotor speed increases above the nominal synchronous speed ns, we have to increase in a negative polarity the frequency of the ac currents that are fed into the rotor. This negative polarity of the frequency f rotor indicates that the phase sequence of the three-phase ac currents fed into the rotor windings, now must make the rotor magnetic field rotate in the opposite direction of the rotor speed, as it was illustrated in Figure 3. 1. b. For a better understandgin, we can make an small example. Consider a doubly-fed induction generator having 4 magnetic poles. The generator supplies power to a 50 Hz ac power network, and the external source makes the generator rotate at a speed of 1980 r/min, the frequency of the ac currents that need to be fed into the generator rotor windings can be calculated so: The frequency f rotor to be fed into the rotor in order to have a frequency f stator of the generator output voltage is equal to the frequency of the ac power network is 16 Hz. The negative polarity of the frequency indicates that, as it was explained before, the magnetic field created in the rotor windings must rotate in the opposite direction of the rotor speed. When we want to produce power in the ac electrical grid with a doubly-fed induction generator, any deviation of the rotor speed from the synchronous speed ns is compensated by varying the frequency of the ac currents fed into the rotor windings in order remain constant (and equal to the network frequency) the frequency of the voltage produced at the stator. In other words, the frequency f rotor is changed to have always constant the nΦ, stator of the rotating magnetic field passing through the stator windings. However, we have to maintain constant not only the output frequency of the stator, but also the voltage produced on it should be equal to the ac power network voltage. Thus, a particular magnetic flux value must be maintained in the stator windings. This can be achieved by applying a voltage to the rotor currents that is proportional to the frequency applied. This maintains the V/f ratio constant and ensures a constant magnetic flux value in the machine. It is like a scalar control in an asynchronous machine, if we maintain this ratio constant, the value of the magnetic field is also constant (for more information, go to section number 7). The value of the V/f ratio is generally set so that the reactive power at the stator Q stator is equal to zero. This has the same meaning as it is done in the conventional synchronous generators where the exciter current (dc current in the rotor) is adjusted in order to have a zero value in the reactive power at the stator.

3. 3. WIND TURBINES WITH DOUBLE FED GENERATORS.

Because of the many advantages that doubly-fed induction generators have over different generators when in our application the mechanical power provided to the rotor varies (such as the wind), the majority of them nowadays are used to generate electrical power in high power wind turbines. However, we need to know a little bit more about large-size wind turbines in order to have a better understanding about the advantages of using doubly-fed induction machines to generate electrical power. There are two different groups of large-size wind turbines, fixed-speed wind turbines and variable-speed wind turbines. Depending on this which one we use, it determines the behaviour of the wind turbine when the wind speed varies. If we use fixed-speed wind turbines, it is normally used asynchronous generators. With this machines, they are directly connected to the electric grid (local ac power network), and the rotation speed of the generator is almost fixed, and it is the rotor speed of the turbine. In the reality, it can usually vary a little as the slip is allowed to vary over a range of typically 2% to 3%. When the wind speed varies causes that the mechanical power at the rotor changes and, due to the fact that the rotation speed is fixed, the torque at the wind turbine rotor has a proportional variation. Because of this, when the winds speed vary, the rotor speed has a small or non-existent variation but the torque at the turbine rotor increases significantly. Therefore, every wind speed variation stresses the mechanical components in the turbine and causes an immediate increase in rotor torque and also in the power at the generator output. This is a problem for the electrical grid where the turbine is connected, because any fluctuation in the output power of a wind turbine generator is a source of instability. In the other hand, we can use variable-speed wind turbines, in which the rotation speed of the turbine rotor is allowed to vary when the wind speed varies. Because of that, the use of asynchronous generators is not recommended because the rotor speed is quasi-constant when they are connected to the grid. Also, it is not recommended to use synchronous generators because they must rotate at the synchronous speed when they are connected directly to the grid. In this point is where the where doubly-fed induction generators increase their importance, because they are able to maintain the output voltage and frequency constant, regardless of generator rotor speed and thus, the wind speed. As it was explained before, this is achieved by changing the frequency and amplitude of the ac currents fed into the generator rotor windings. By this process, it is possible to remain constant the amplitude and frequency of the voltages at stator produced by the machine, even if the wind turbine rotor speed has some variations caused by changes in the wind speed. This speed variation possibility has another consequence. The generator avoid the suddenly torque variations at the wind turbine rotor, and this decrease the stress caused on the mechanical components of the machine. Also, there are no variations in the amount of electrical power produced by the generator. Furthermore, it is possible to adjust the power factor of the system by changing the amount of reactive power exchanged between the generator and the ac power network. Finally, if we use a doubly-fed induction generator in variable-speed wind turbines, it is possible to generate power at lower wind speeds than with fixed-speed wind turbines using asynchronous generators. It is possible to obtain similar results for variable-speed wind turbines using a three-phase synchronous generator with power electronics, as shown in Figure 3. 2 a. In this application the rotor speed is proportional to the wind speed, and the frequencies of the ac currents produced by the generator are variable. In order to connect the machine to the network, it is needed to convert them into dc current by an AC/DC converter (rectifier), and then converted by another AC/DC converter (inverter) to ac currents that are synchronous with the ac power network. Thus, the power electronics devices used in this application has to process the 100% of the generator output power. In the other hand, the power electronics devices used in doubly-fed induction generators, only process a fraction of the generator output power. The electronic devices only have to control the power fed to or from the rotor windings, which is typically about 30% of the generator total power. Thus, if we use a doubly-fed generator for variable-speed wind turbines, the power electronics devices can be smaller and cheaper, with tipically about the 30% of the size of the power electronics devices used for three-phase synchronous generators, as illustrated in Figure 3. 2 b. This reduces the cost of installation, as well as the power losses in the system. Figure 3. 2. a Circuit topologies for two types of generators found in variable-speed wind turbines. Figure 3. 2. a Circuit topologies for two types of generators found in variable-speed wind turbines. In conclusion, using a doubly-fed induction generator in wind turbines offers the next advantages: Operation at variable rotor speed maintaining constant the amplitude and frequency of the generated voltages. Optimization of the amount of power generated as a function of the wind available up to the nominal output power of the wind turbine generator. Virtual elimination of dangerous variations in the torque and power generated. Generation of electrical power at lower wind speeds. Control of the power factor. On the other hand, the doubly-fed induction generator has some inconvenient. They require more complex power conversion circuitry than the asynchronous generator. Also, in order to have an implementation of the doubly-fed induction generator it is needed slip rings on the wound-rotor induction machine, and they require periodic maintenance. However, in a asynchronous generator rings are not required on the rotor of the squirrel-cage. If we compare the use with a synchronous generator in wind turbines, they offer the same advantages as doubly-fed induction generator. Both types of generator require two AC/DC converters. However, as it was explained, the two AC/DC converters in doubly-fed induction generators are significantly smaller than those in synchronous generators of comparable output power. This is because the AC/DC converters in doubly-fed induction generators work with only about 30% of the nominal generator output power while the AC/DC converters in synchronous generators control the 100% of the nominal generator output power.

4. EQUIPMENT USED.

4. 1. LABVIEW.

LabVIEW is the short name for Laboratory Virtual Instrument Engineering Workbech. Is a language and at the same time an environment for graphical programming which allow us to create different applications. First of all, it is going to be showed the history of the program. LabVIEW was developed by National Instruments and they began in 1976 in Austin, Texas and its first products devices were for the instrumentation bus GPIB. In April 1983 they began development of LabVIEW, which was an important goal for the company, and it becomes their best product. It was released in October 1986 with the release of LabVIEW 1. 0 for Macintosh and version 2. 0 in 1990. For Windows would have to wait until September 1992. LabVIEW is a useful graphical development environment with integrated functions for performing data acquisition, control instruments, measurement analysis and data presentation. This program offers the flexibility of a powerful programming environment but, through the graphic programming, is more simply than other languages. Unlike general purpose languages, LabVIEW provides specific functionality that can accelerate the development of measurement, control and automation. It has different tools for building applications with no text lines of code, only with functions and blocks. Also, we can place objects and then create user interfaces. After we have to specify the system functionality with the block diagrams. With LabVIEW we can develop systems that meet our performance requirements in different systems such as Windows, Macintosh, UNIX and real-time systems. Furthermore, it works with more than one thousand instruments libraries of manufacturers, and many manufacturers of measuring devices also include with their products tools. With this program, it is not only the performance or the simply programming, but also the reasonable cost of designing an application. The program has extensive capabilities for acquisition, analysis and presentation, so that it can create a comprehensive solution on the platform that has chosen. We are going to use the Real-Time module for LabVIEW, in order to design real time applications and take advantage of our multicore CPU.

4. 1. 1 LABVIEW REAL TIME.

For our application, we are going to develop a program that controls the motor in real time. We need to read some values (like the speed) and generate the ac voltages in each moment. Some others applications can run on general-purpose operating systems like Microsoft Windows. However, our applications require deterministic real-time performance that non-real-time operating systems like Windows cannot guarantee. LabVIEW Real-Time (RT) addresses the need for deterministic real-time performance. This part of the program combines the use of LabVIEW with the power of real-time systems so we can create deterministic applications using graphical programming. In order to build Real-time applications we need RT Series hardware, either plug-in data acquisition devices or networked RT Series devices. Thus, we are going to use embedded LabVIEW RT applications in a PXI device. However, these devices do not have a user interface, so they must have a host PC to generate the user interface. Because of that, we will develop our basic program from a host system with Windows. Then, when the program is ready in the host system, we can download the real-time code to run it on a hardware target (or PXI system) with a real-time module. This process will be explained in the section number five. The general purpose operating systems can have some problems, such as delays or crashes, which causes programs to quit running and this could be a very important problem in the real industry. This is the main reason why we are going to use a real time system. Even if the host PC operating system crashes, due to the fact that embedded real time applications run on a separate hardware platform, they do not stop executing. If a crash occurs on the host system, the user interface is lost, and any other communication between an embedded LabVIEW RT application and the host PC ceases. However, the embedded applications keep on running, even after the host PC operating system crashes. Once we have rebooted the host Pc without disrupting embedded the real time application, we can re-establish communication between the host PC and the embedded real time program and continue working normally. For our objective, we need a real time application, in order to control our motor in each moment. A general-purpose system like windows could send the information with some delay, causing a wrong control. This even could cause that the IGBT'S do not create an alternative current because they do not change their state, or a short-circuit between two IGBT's in the same branch. In order to use the real time application, we need a PXI-chassis, a PXI-controller and some acquisition devices that will be explained in the following sections. To communicate the host PC and our PXI device, we connect them with an Ethernet connexion, as we can see in the next figure. Figure 4. 1. Connexion between the host Pc and the PXI chassis.

4. 2. PXI DEVICES.

PCI eXtensions for Instrumentation (PXI) are a compact and resistant PC based on a platform that offers a high performance capacity for measurement and automation systems. The system has an electrical bus called Peripheral Component Interconnect (PCI) combined with the modular Eurocard mechanical packaging of CompactPCI and also, it has buses for a high synchronization and good software features. PXI has also mechanical, electrical, and software features that make it suitable for testing systems or measurements, analog and digital data acquisition and also manufacturing applications such as automation. We can use this system for different applications such as manufacturing test, military and aerospace, machine monitoring, automotive, and industrial test. In our case, we will use it for machine control and monitoring. National Instruments started with the PXI systems in 1997 and one year later it was announced that it was going to be an open industry, in order to deal with the necessity of complex instrumentation systems. Because of that, any company has the possibility to build PXI products. Due to this, the interoperability between CompactPCI and these new products is an obliged feature of the PXI specification, and different kinds of CompactPCI and PXI modules can work in a PXI system without having any kind of compatibility problem. Later, in 2005 the technology evolved improving the available bus bandwidth capability, so they announced the change from PCI to PCI Express, and from PXI to PXI Express. Only using the new PCI Express in a PXI standard system, the system has the ability to be used even in more application because of the new performance. The new PCI Express technology can be installed into the backplane and they are totally compatible with all the parts installed for previous systems. PXI Express have increased the bandwidth from 132 MB/s to 6 GB/s by taking advantage of the new PCI Express technology, and this means a very high evolution. Furthermore, as we have explained, the system still maintains its compatibility with software and hardware from other PXI systems. With this new bus bandwidth performance, PXI can be used in a lot of new application areas that need powerful systems. As we can see in the next figure, every PXI system has three basic parts: the chassis, the system controller and peripheral modules. In the next sections it will be explained separately. Figure 4. 2. PXI system.

4. 2. 1. CHASIS PXI 1031.

The chassis is the basis for the system. We can chose between different chassis, with different features such as number of slots, sizes and power supplies (AC and DC). Some chassis can have PXI and PXI Express peripheral modules and other systems only have hybrid and PXI Express slots and because of this we can only use peripheral modules with PXI Express and hybrid-compatible PXI technologies. The chassis can have several PXI system configurations to be able to adapt different needs. They have a high-performance backplane, because this backplane includes the PCI bus and independently timing and triggering buses. Also, this modular configuration adds a 10 MHz system reference clock, PXI trigger bus, star trigger bus, and slot-to-slot local bus to solve the need for advanced timing, synchronization, and sideband communication and at the same time without losing any PCI advantages. Figure 4. 3. PXI timing and triggering busses. Improving the PXI communication capacities, PXI Express provides an additionally 100 MHz differential system clock, timing and synchronization features of differential signalling, and differential star triggers. Because of this differential clock and high synchronization, PXI Express systems are more immune to noise problems for instrumentation clocks and they can transmit information at higher frequency speeds. If we use these timing and triggering buses, it can be developed systems for applications that require precise synchronization. In our project, we are going to use a PXI 1031 chassis. It combines a 4-slot PXI backplane that has been designed to be used in a wide range of applications, this means that is a general chassis for different needs. It accepts 3U PXI and CompactPCI (PICMG 2. 0 R 3. 0) modules. The chassis should be fed with AC, and it has an automatic voltage and frequency ranging. Furthermore, it has a controlled fan speed based on air to control automatically the temperature, but at the same time, minimizing the audible noise. In the next figure, we can see the front panel of the PXI 1031 with its different parts. Figure 4. 4. Front panel of PXI 1031. The PXI-1031 backplane should be used with 5V, universal PXI-compatible products and standard CompactPCI products. This is an important feature, because some PXI systems may require components that do not implement PXI-specific features. As we can see in the figure 4. 4, the slot number one of the chassis is the system controller. It has three controller expansion slots for different system controller modules. As it is defined in the PXI specification, these slots allow the controller to expand to the left to prevent the controller from using peripheral slots. The slot number two is the star trigger (ST). This slot has dedicated equal-length trigger lines between slot 2 and peripheral slots 3 and 4. It is intended for modules with ST functionality that can provide individual triggers to all other peripheral modules. However, if in our application is not required advanced trigger functionality, we can install here any normal peripheral module. There are three peripheral slots, including the star trigger slot that we can use for different kind of measurements. The PXI backplane local bus is connects each peripheral slot with adjacent peripheral slots to the left and right connected in series. Each local bus has thirteen lines wide and can pass analogue signals up to 42 V between cards or provide a high-speed TTL side-band digital communication path without reducing the PXI system bus bandwidth. All slots share eight PXI trigger lines. One option to use these trigger lines could be to synchronize the operation of several different PXI peripheral modules, but it can be used in several applications. Besides, the PXI-1031 supplies the PXI 10 MHz system clock signal independently to each peripheral slot. An independent buffer drives the clock signal to each peripheral slot. We can use this common reference clock signal to synchronize multiple modules in a measurement or control system. All this explication is resumed in the figure 4. 3 that it was seen before. Our system needs some inputs parameters that we can find it in the user manual of the manufacture. Table 4. 1. Input values. Also, we should need the DC output parameters in order to connect other devices to our PXI system. Table 4. 2. DC current capacity. Table 4. 3. Protections.

4. 2. 2. CONTROLLER PXI 8106.

As we have seen in the previous point, the chassis PXI 1031 slot 1 is used to install a system controller. When we are looking for the best system controller for an application, we can choose from some options. For example, remote controllers from a desktop, workstation, server, or using a computer and high-performance embedded controllers with Microsoft OS (Windows 7/Vista/XP) or a real-time OS(LabVIEW Real-Time). There are two options to control a PXI system, from a laptop control or from a PC. The PXI embedded controllers eliminate the need for an external PC because of the fact that they are, with the PXI chassis, a complete system. Because of this, the controllers are provided with standard characteristics like an integrated CPU, hard drive and RAM memory, Ethernet connexion, video output, keyboard/mouse, serial, USB connexion and other peripherals. Also, they have installed Microsoft Windows and all the drivers needed. There are controllers for systems based on PXI or PXI Express, and there are different options to decide the operating system, depending on ours necessities. It could be Windows 7, 8, Vista and XP, or LabVIEW Real-Time. In our case, we are going to use the controller with LabVIEW real time, and use an external PC to control de user interface. The PXI embedded controllers are built with standard PC components in a small package. If we need to have a portable systems or applications where the chassis is moved from one location to others, embedded controllers are ideal. In our case, we can use the PXI embedded controller to develop the speed control and use it in different machines, in different places. In the next figure we can see our PXI 8106 controller. Figure 4. 5. PXI 8106 Controller. For our project, it will be used the PXI 8106. This embedded computer is a high-performance PXI system controller, which integrates standard input and output features in a single unit by using state-of-the-art packaging. As we did, combining this controller with our PXI 1031 chassis, results in a fully PC-compatible computer in a compact and rugged package. The standard I/O on this module includes DVI-I (Digital Video Interface Integrated Analog/Digital) video, one RS-232 serial port, a parallel port, four Hi-Speed USB ports, Gigabit Ethernet, a reset button, and a PXI trigger. The controller has an Intel ® Core 2 ™ Duo processor T7400 (2. 16 GHz dual core processor), all the standard I/O, and a 30 GB hard drive. It also has a PCI-based GPIB controller and an ExpressCard/34 expansion slot. The PXI controller 8106 is a modular PC in a PXI 3U-size form factor. In the next figure we can see a functional block diagram of the machine. Following the diagram is a description of each logic block shown. Socket 479CPUDUAL CHSO-DIMMDDR2 SDRAMPC2-5300

Chipset

GraphicsMemoryControllerHubFlahs ROMDMIGPIBGigabitEthrenet

Chipset

I/OControllerHubPXI connectorPXItrigger4-Hi speed USB connectorsPCI busCOM 1LPT 1SuperI/OExpresscard /34 SlotSATAATA 100 IDE interfaceLPC busSMBSMB to PXITriggerWatchdog timerFigure 4. 6. Block diagram. Our chassis CPU module is formed with the logic blocks of the figure 4. 6, that are explained in the following points: The first one is the Socket 479 CPU, and is the Intel ® Core 2 ™ Duo processor T7400. The SO-DIMM block consists of connections of 64-bit DDR2 SDRAM that, as maximum, can have 1 GB each one. The Chipset 945GMCH (Graphics and Memory Controller Hub) establish the connection between the DDR2 SDRAM and DVI-I video, with the CPU. The SMB to PXI Trigger creates a connection of the PXI triggers to the SMB on the front panel and also from it. Also, we have the Watchdog Timer block is a timer that can generate a trigger signal or reboot the computer if there is any problem. The Chipset ICH7M is used to connect the PCI, USB, IDE, SATA, and LPC buses. To this ICH7M chipset, we have connected the USB Connectors. The SATA block is used to make a connexion between a Serial ATA and the ICH7M chipset. The ATA-100 IDE block is dedicated PCI-IDE circuitry providing fast communication to 2. 5’’ hard drive that has at least 30 GB. Then, as we can see in the diagram, the PXI Connector connects the controller to the PXI backplane. The Super I/O block represents the other peripherals supplied by the PXI 8106 controller. Also, it has one serial port, and an ECP/EPP parallel port. The Gigabit Ethernet we are going to use to connect the controller with the host PC, connects to a 10 Mbit, 100 Mbit, or 1, 000 Mbit Ethernet interfaces. The GPIB block contains the GPIB interface, and the ExpressCard-34 slot has an ExpressCard-34 module. We have to set our processor in our chassis following the installation procedure. We are going to use LabVIEW real time in our processor, so we have to configure it in order that it always start in a real time mode. We must configure the switches that we can see in the next figure, and the controller will read it after a system reset. If we set the switch 1(boot LabVIEW RT) to on position, it starts with LabVIEW RT. The switch 2(boot Safe Mode), if we set this switch to on the controller boots LabVIEW RT in safe mode to reconfigure TCP/IP directions and also we can download or update software from another computer connected to the controller. The switch 2 is predominant over the behaviour of switch 1. If we boot the controller into safe mode, LabVIEW RT is not going to start. We should reboot the controller with this switch off to resume normal operation, after changing the settings or software. The switch 3 (disable Startup VI) is used to prevent that one program starts automatically running if the controller becomes inaccessible. The switch 4 (reset IP address) is used to reset to a default configuration the IP address and other TCP/IP settings. This bottom is only used if we are going to move the controller to another subnet or the current values of the TCP/IP are not valid. Figure 4. 7. Controller configuration. The controller has in the front-panel some important features that we should know. A controller reset pushbutton and two front panel LEDs that show PC status: The power led ok, is used to show the user the power status of the controller. The LED can be on, that means that PXI and onboard power is on and within regulation limits. Also, the LED can be blinking if one of the PXI or onboard supplies is operating outside of the normal limits, or is not functioning. The last option is that the LED is off, when the controller has no power connection. The drive

LED indicates that the controller is accessing to the hard disk. We have two different possibilities for data storage. We can use the internal hard drive (2. 5’’) that supports up to ATA-5 (UDMA 100) for extended temperatures or SATA for standard configuration. Also, we can use a USB storage support, such as USB CD-ROM, mass storage device, or floppy drive. Table 4. 3. Electrical specifications.

4. 2. 3. PERIPHERICAL MODULES. PXI 6221.

The options to choose a PXI module are wide. This modules are not offered only by National instruments (with more than 200 different), but also by more than 70 vendors (with more than 1, 500 modules) because now, as it was explained before, is an open industry. We can use them for a lot of applications such as analog input or output, digital input or output, digital signal processing, motion control, signal generation, data acquisition, switching, vision, advanced synchronization, and interfacing with other buses so we can create a wide variety of PXI systems. In our project, we are going to use a PXI 6221 to have digital inputs (for the speed sensor), digital outputs (for the IGBT’s controlling) and also analog inputs (for the current measurement). It is a multifunction M Series data acquisition (DAQ) board optimized for sensitive applications. It was chosen this board because of its high speed for sampling and the accuracy for a hight resolution and superior measurement accuracy. All of this is why this device incorporates advanced features such as the NI-STC 2 system controller, NI-PGIA 2 programmable amplifier, and NI-MCal calibration technology to increase performance and accuracy. First of all, we are going to use this device to digital I/O. It has twenty-four digital channels: eight digital channels (P0. 0 to P0. 7) and sixteen PXI channels (PFI0 to PFI15). Each channel has an input voltage protection when the value is more than 20 V. It also has two counters with 32-bits resolution for edge counting, pulse, period and two edge separation that are thought to be used in the speed measurement, in order to count pulses. The device has also eight differential analog inputs and 2 analog outputs, that we are going to use to the I measurement. In the next figure we can see the PXI 6221 pinout. Figure 4. 8. PXI 6221 pinout (68 pin). In the next table it is described the signals found on the I/O connectors. Table 4. 4. I/O connector signals. (From " SCB-68 user manual for advanced functions"). Once we have our PXI chassis 1031, our PXI controller 8106, and our PXI data acquisition device 6221, we are ready to use them with LabVIEW real time applications. We can see our real system in the next figure: Figure 4. 9. Real system.

4. 3. SCB 68.

The SCB-68 is an input/output connector block with 68 connections in order to use it with a 68-pin DAQ device. The SCB-68 features a general board for custom circuitry and sockets for interchanging electrical components. In this connexions we can filter 4 to 20 mA current input measurement, open thermocouple detection, and voltage attenuation. The open components allow us to add signal conditioning to the analog input (AI), analog output (AO), and PFI 0 signals of a 68-pin DAQ device. In the next table is going to be shown the connexions of the SCB-68. Table 4. 5 SCB-68 connexions. Figure 4. 10. Board diagram. As we see in the figure, there are five switches, S1 to S5 that we should configure. We need a direct feed through mode because with it, all 68 signals from the device connect directly to screw terminals. Once done this, the device is ready to our proposal.