Applications of Multilevel Inverters in AC Drives

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Abstract: **Multilevel converters are increasingly being considered for high power applications because of their ability to operate at higher output voltages while producing lower levels of harmonic components in the switched output voltages. Two well known multilevel converter topologies are the Neutral Point Clamped (NPC) Inverter and Cascaded inverter.One of the major problems in electric power quality is the harmonic contents. There are several methods of indicating the quantity of harmonic contents. The most widely used measure is the total harmonic distortion (THD). Various switching techniques have been used in static converters to reduce the output harmonic content. Pulse Width Modulation techniques for multilevel inverters have been developed very intensively in recent years. Many carriers based and sinusoidal PWM (SPWM) techniques for multilevel inverters have been properly deduced from that of two-level inverter. In this paper, applications of multilevel inverters in AC drives are presented.**

Keywords: Multilevel inverters, AC Drives, Drives, PWM techniques.

I. INTRODUCTION

In general, increasing the switching frequency in voltage source inverters (VSI) leads to the better output voltage / current waveforms. Harmonic reduction in controlling a VSI with variable amplitude and frequency of the output voltage is of importance and thus the conventional inverters which are referred to as two-level inverters have required increased switching frequency along with various PWM switching strategies. In the case of high power / high voltage applications, however, the two-level inverters have some limitations to operate at high frequency mainly due to switching losses and constriction of device rating itself. Moreover, the semiconductor switching devices should be used in such a manner as problematic series / parallel combinations to obtain capability of handling high power. Nowadays the use of multilevel approach is believed to be promising alternative in such a very high power conversion processing system. Advantages of this multilevel approach include good power quality, good electromagnetic compatibility (EMC), low switching losses, and high voltage capability.

Most of the industrial motor applications use AC induction motors. The reasons for this include high robustness, reliability, low price and high efficiency. Industries have many applications, where variable operating speed is a prime requirement. Principal benefits of variable speed drives in industrial applications are that they allow the drive speed and torque to be adjusted to suit the process requirements. In many applications, operating the plant at a reduced speed when full output is not needed produces a further important benefit: energy savings and reduced cost. Plant wear and hence, maintenance requirements, are also minimized by operation at reduced speed. The various methods of speed control of squirrel cage induction motor through semiconductor devices are given in [1, 2 and 4].

II. CONTROL OF AC DRIVES

Constant voltage/hertz control is one of the popular methods for speed control of induction motor. This aims at maintaining the same terminal voltage to frequency ratio so as to give nearly constant flux over wide range of speed variation. In this control scheme, the performance of machine improves in the steady state only, but the transient response is poor. More over Constant voltage/hertz control keeps the stator flux linkage constant in steady state with out maintaining decoupling between the flux and torque [1].

The history of electrical motors goes back as far as 1820, when Hans Christian Oersted discovered the magnetic effect of an electric current. One year later, Michael Faraday discovered the electromagnetic rotation and built the first primitive D.C. motor. Faraday went on to discover electromagnetic induction in 1831, but it was not until 1883 that Tesla invented the A.C. asynchronous motor.

Currently, the main types of electric motors are still te same, DC, AC asynchronous and synchronous, all based on Oested, Faraday and Tesla’s theories developed and discovered more than a hundred years ago.

Since its invention, the AC asynchronous motor, also names induction motor has become the most widespread electrical motor in use today.

These facts are due to the induction motors advantages over the rest of the motors. The main advantage is that induction motors do not require an electrical connection between stationary and rotating parts of the motor. Therefore, they do not need any mechanical commutator (brushes), leading to the fact that they are maintenance free motors. Induction motors also have low weight and inertia, high efficiency and a high overload capability. Therefore, they are cheaper and more robust, and less proves to any failure at high speeds. Furthermore, the motor can work in explosive environments because no sparks are produced.

Taking into account all the advantages outlined above, induction motors must be considered the perfect electrical to mechanical energy converter. However, mechanical energy is more than often required at variable speeds, where the speed control system is not a trivial matter.

The only effective way of producing an infinitely variable induction motor speed drive is to supply the induction motor with the three phase voltages of variable frequency and variable amplitude. A variable frequency is required because the rotor speed depends on the speed of the rotating magnetic field provided by the stator. A variable voltage is required because the motor impedance reduces at low frequencies and consequently the current has to be limited by means of reducing the supply voltages.

Before the days of power electronics, a limited speed control of induction motor was achieved by switching the three-stator windings from delta connection to star connection, allowing the voltage at the motor windings to be reduced. Induction motors also available with more than three stator windings to allow a change of the number of pole pairs. However, a motor with several windings is more expensive because more than three connections to the motor are needed and only certain discrete speeds are available. Another alternative method of speed control can be realized by means of a wound rotor induction motor, where the rotor winding ends are brought out to slip rings. However, this method obviously removes most of the advantages of induction motors and it also introduces additional losses. By connecting resistors or reactance in series with the stator windings of the induction motors, poor performance is achieved.

At that time the above described methods were the only ones available to control the speed of induction motors, whereas infinitely variable speed drives with good performances for DC motors already existed. These drives not only permitted the operation in four quadrants but also covered a wide power range. Moreover, they had a good efficiency, and with a suitable control even a good dynamic response. However, its main drawback was the compulsory requirement of brushes.

However, one precondition had to be made, which was the development of suitable methods to control the speed of induction motors, because in contrast to its mechanical simplicity their complexity regarding their mathematical structure (multivariable and non-linear) is not a trivial matter. It is in this field, that considerable research effort is devoted. The aim being to find even simpler methods of speed control for induction machines one method, which is popular at the moment, is Direct Torque Control.

III. Several Controllers

Historically, several controllers have been developed:

- Scalar controllers: Despite the fact that "Voltage-Frequency" (V/f) is the simplest controller, it is the most widespread, being in the majority of the industrial applications. It is known as a scalar control and acts by imposing a constant relation between voltage and frequency. The structure is very simple and it is normally used without speed feedback. However, this controller does not achieve a good accuracy in both speed and torque responses, mainly due to the fact that the stator flux and torque are not directly controlled. Even though, as long as the parameters are identified, the accuracy in the speed can be 2% (expect in a very low speed), and the dynamic response can be approximately around 50ms.

- Vector controllers: In these types of controllers, there are control loops for controlling both the torque and the flux. The most widespread controllers of this type are the ones that use vector transform such as either Park or Ku. Its accuracy can reach values such as 0.5% regarding the speed and 2% regarding the torque, even when at standstill. The main disadvantages are the huge computational capability required and the compulsory good identification of the motor parameters.
- Field Acceleration method: This method is based on maintaining the amplitude and the phase of the stator current constant, whilst avoiding electromagnetic transients. Therefore, the equations used can be simplified saving the vector transformation, which occurs in vector controllers. This technique has achieved some computational reduction, thus overcoming the main problem with vector controllers and allowing this method to become an important alternative to vector controllers.

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