Control Strategy of PWM Three-Level NPC Inverter for Power Quality Assimilation of Energy Resources in to Grid Distribution

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Abstract-

The power electronics device which converts DC power to AC power at required output voltage and frequency level is known as inverter. Inverters can be broadly classified into single level inverter and multilevel inverter. Multilevel inverter as compared to single level inverters have advantages like minimum harmonic distortion, reduced EMI/RFI generation and can operate on several voltage levels. A multi-stage inverter is being utilized for multipurpose applications, such as active power filters, static var compensators and machine drives for sinusoidal and trapezoidal current applications. The drawbacks are the isolated power supplies required for each one of the stages of the multiconverter and it's also lot harder to build, more expensive, harder to control in software. This project aims at the simulation study of three phase single level and multilevel inverters . The role of inverters in active power filter for harmonic filtering is studied and simulated in MATLAB/SIMULINK. Firstly, the three phase system with non-linear loads are modeled and their characteristics is observed . Secondly, the active power filters are modeled with the inverters and suitable switching control strategies (PWM technique) to carry out harmonic elimination .

Keywords:- *Multilevel inverter, harmonic, transmission lines, photovoltaic*

Introduction

When ac loads are fed through inverters it required that the output voltage of desired magnitude and frequency be achieved. A variable output voltage can b obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally acco3mplished by pulse-width-modulation (PWM) control within the inverter. The inverters which produce which produce an output voltage or a current with levels either 0 or +-V are known as two level inverters. In high-power and high-voltage applications these two-level inverters however have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. This is where multilevel inverters are advantageous. Increasing the number of voltage levels in the inverter without requiring higher rating on individual devices can increase power rating. The unique structure of multilevel voltage source inverters' allows them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized-switching devices. The harmonic content of the output voltage waveform decreases significantly. Multilevel inverters have been under research and development for more than three decades and have found successful industrial applications. However, this is still a technology under development, and many new contributions and new commercial topologies have been reported in the last few years. The aim of this dissertation is to group and review recent contributions, in order to establish the current state of the art and trends of the technology to provide readers with a comprehensive and insightful review of where multilevel converter technology stands and is heading. This chapter first presents a brief overview of well-established multilevel inverters strongly oriented to their current state in industrial applications and then centers the discussion on the new multilevel inverters that have made their way into the industry. Multilevel inverters have been attracting increasing interest recently the main reasons are; increased power ratings, improved harmonic performance, and reduced electromagnetic interference (EMI) emission that can be archived with multiple dc levels that are synthesis of the output voltage waveform. In particular multilevel inverters have abundant demand in applications such as medium voltage industrial drives, electric vehicles, and grid connected photovoltaic systems. The present work provides a solution to design an efficient multilevel topology which is suited for medium and high power applications. In the subsequent sections the research background is discussed in detailed. Motivation and objectives are clearly outlined. There are different power converter topologies and control Strategies used in inverter designs. Different design approaches address various issues that may be more or less important depending on the way that the converter is intended to be used. The issue of waveform quality is one the important concern and it can be addressed in many ways. In practice capacitors and inductors can be used to filter the waveform [1-2]. If the design includes a transformer, filtering can be applied to the primary or the secondary side of the transformer or to both sides. Low-pass filters are applied to allow the fundamental component of the waveform to pass to the output while limiting the passage of the harmonic components. Thus quality of waveform can be adjusted. Note that, normal inverters always generate very low quality output waveforms. To make the output waveform qualitative, low pass (LC filter) are often added in the circuit. Thus, at this point of time readers might have a question that, why the quality of converter output is low? And why Low pass filter are frequently added in the circuit. Further, what kinds of solutions are available to increase quality of output waveform without losing its efficiency? All this are open problems associated with present day inverters. However, eventually all this will be addressed in this thesis. But at first we try to figure out the converter applications from low power to high power and then we summarize the requirements to meet the high power demand. Finally we try to present the problems and solutions available to meet the high power demand. which presents the important applications from low power to high power range. From it is quite predictable that, power inverters are an enabling technology. They are potentially useful for a wide range of applications like; low power devices, home appliances, electric vehicles, photovoltaic, transport (train traction, ship propulsion, and automotive applications), and energy conversion, manufacturing, mining, and petrochemical applications. The inverters mentioned in are available in a wide range. Note that, either it may be suited for DC or AC. But, at present industries are in chase of finding new type of power converter for medium to high power range, moreover it seems to be challenging issues for present generation researchers

Power Inverters

Although research pioneers have built a numerous power inverters, but still researchers are in look for a new sort of architecture which can produce high quality waveform with less number of components. In other terms improving power quality is the greatest requirement. By considering above aspects, let us make an outline regarding the demanding aspects of power inverters, particular in Medium and high power range.

	Low Power	Medium Power	High Power
Power Range	Up to 2 KW	2-500 KW	More Than 500 KW
Usual Converter Topologies	ac/dc, dc/dc	ac/dc, dc/dc, dc/ac	ac/dc, dc/ac
Typical Power Semiconductors	MOSFET	MOSFET, IGBT	IGBT, IGCT, Thyristor
Technology Trend	High Power Density, High Efficiency	Small Volume and Weight Low Cost and High Efficiency	High Nominal Power of the Converter high Power Quality and Stability
Typical Applications	Lower-Power Devices; Home Appliances	Electric Vehicles; Roof PV	Transportation; Power Distribution; Renewable Energy; Industry

Fig1 . Power Inverters

The current energy arena is changing. The feeling of dependence on fossil fuels and the progressive increase of its cost is leading to the investment of huge amounts of resources, economical and human, to develop new cheaper and cleaner energy resources not related to fossil fuels [3]. In fact, for decades, renewable energy resources have been the focus for researchers, and different families of power inverters have been designed to make the integration of these types of systems into the distribution grid a current reality. Besides, in the transmission lines, high-power electronic systems are needed to assure the power distribution and the energy quality. Therefore, power electronic inverters have the responsibility to carry out these tasks with high efficiency. The increase of the world energy demand has entailed the appearance of new power converter topologies and new semiconductor technology capable to drive all needed power. A continuous race to develop higher-voltage and higher-current power semiconductors to drive high-power systems still goes on. However, at present there is tough competition between the use of classic power converter topologies using high-voltage semiconductors and new converter topologies using medium-voltage devices. Power inverters are an amazing technology for industrial practice powered by electric drive systems. They are potentially helpful for a wide range of applications: transport (train traction, ship propulsion, and automotive applications), energy conversion, manufacturing, mining, and petrochemical, to name a few. Many of these processes have been continuously raising their demand of power to reach higher production rates, cost reduction (large-scale economy), and efficiency [4]. The power electronics research community and industry have reacted to this demand in two different ways: developing semiconductor technology to reach higher nominal voltages and currents (currently 8 kV and 6 kA) while maintaining traditional converter topologies (mainly two-level voltage and current source inverters); and by developing new converter topologies, with traditional semiconductor technology, known as multilevel inverters [5]. The first approach inherited the benefit of well known circuit structures and control methods. Adding to that, the newer semi-conductors are more expensive, and by going higher in power, other power-quality requirements have to be fulfilled, thereby there may be need of additional power filters. Therefore it will be quite feasible to choose to builda new converter topology based on multilevel concept. This is the challenging issue right now At present there is tough competition between the use of classic power converter topologies using high-voltage semiconductors and new converter topologies using medium-voltage devices. This idea is shown in Fig.where inverters are built by adding devices in series. In past, these inverters are only viable options for medium and high-power applications. But in present scenario, multilevel technology with medium voltage semiconductors are fighting in a development race with classic power inverters using high-power semiconductors, which are under continuous development and are not mature. Although, classical inverters are good for low power applications, but they fail to fill the requirements of high-power levels.

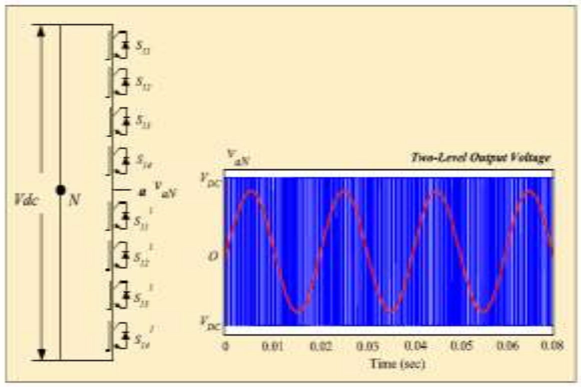

Fig.2Classical converter and output waveform

In view of later, to retrieve the demerits of classical inverters we should know about the multilevel technology and the merits it offer. Multilevel inverters are a good alternative for power applications due to the fact that, they can achieve high power using mature medium-power semiconductor technology. Practically, multilevel inverters present great advantages compared with conventional and very well-known two-level converter. These advantages are fundamentally focused on improvements in the output signal quality (Voltage & Current) and a nominal power increase in the converter [6]. These properties make multilevel inverters very attractive to the industry and, nowadays, researchers all over the world are spending great efforts trying to improve multilevel converter performances such as the control simplification and the performance of different optimization algorithms in order to enhance the THD [7] of the output signals, the balancing of the dc capacitor voltage [8], and the ripple of the currents. For instance, nowadays researchers are focused on the harmonic elimination using pre-calculated switching functions, harmonic mitigation to fulfill specific grid codes, the development of new multilevel converter topologies (hybrid or new ones), and new control strategies [9]. However, before introducing about the multilevel inverters, let’s make an overview about the classical inverters and their problems. To address the problems of conventional inverters, one should have an idea about the Medium to high-power range inverters and related challenging issues. Below are some of the facts summarized.

1. At present, application power range of inverter circuits using the basic "inverter leg" building block is vast (<1 kW to 10 MW+)

2. Very large application area is in industrial (PWM controlled induction motor) drives (See Fig.3) are around 3 kW to 100 kW power range. IGBT devices are used almost exclusively in this power range.

3. Recently the application area for these circuits has extended to power levels (>1 MW), Most importantly,

Wind Power

With increasing energy demands, wind energy becomes a very popular option due to the recent change in the public opinion towards protecting the environment. And it is also viewed as a safe energy source that does not rely on any limited resources. the worldwide usage of wind power. Wind power is harnessed when wind forces the turbine blades to rotate. The spinning of the blades rotates the rotor of the motor, which generates electricity through the wind turbine generator. This motion is then converted into electrical power delivered to the grid. In recent decades, wind energy technongy has rapaily evoloving with the increasing demands for wind power plant stability . This section will discusess the stability of the variable speed Double fed induction generator (DFIG) wind turbine in wind power plant. Wind turbine produces eletricity by using the power of the wind to drive an electrical generator. Wind passes over the blades to excerting a turning forces to turns the shaft inside the wind turbine, which goes into a gearbox. The gearbox increases the rotational speed to induces an magnatic field in the generators, and then converted into electrical energy.

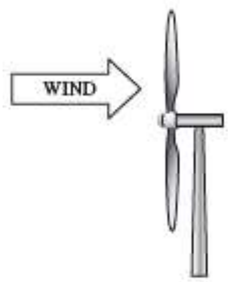

Fig 3 Wind turbine model

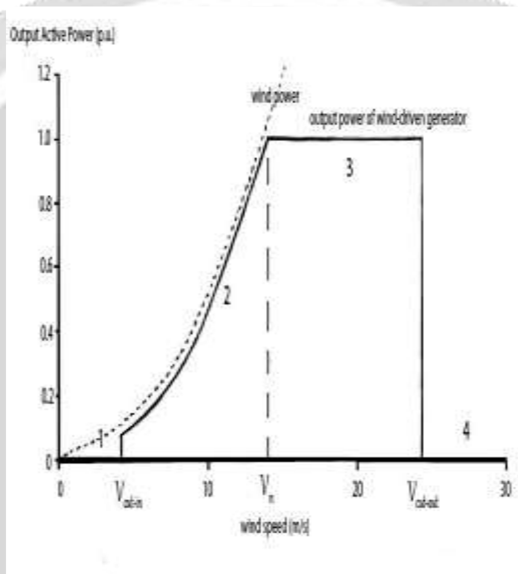

Fig.4 Wind turbine power generating versus wind speed

The graph gave three key factors on the characteristic of wind turbine power output: Cut-in wind speed: the minimum wind speed at which the machine will deliver power.
1. Rated wind speed: the wind speed at which rated power of wind turbine is obtained. The rated power is the maximum power output of the wind turbine generator. 2. Cut-out wind speed: The maximum wind speed at which the turbine is allowed to deliver power or the limited wind speed a wind turbine can operates These characteristic described above are vaired depending on the type of wind turbine

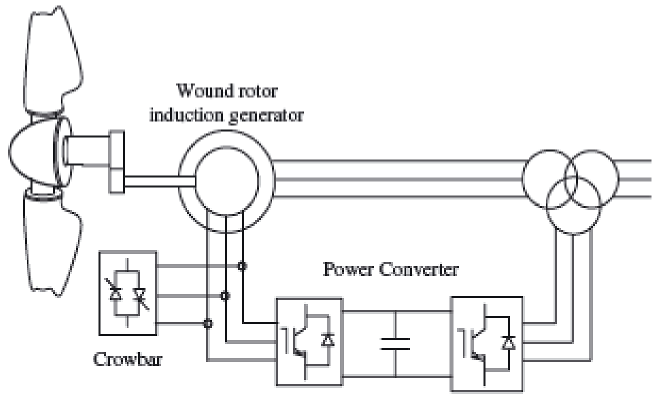

Fig. 5. DFIG wind turbine model

DFIG wind turbine deliver power through the stator and rotor of the generator, while the rotor can also absorbe power depends on the rotational speed of the generator. If the generator operates above synchronous speed, the power are deliverd from the rotor thorugh the power converter to the grid. If the generator is operates below sychronous speed, then the rotor will absorb power from the grid thorugh the power converter. The power converter are consists of a Rotor-side converter (RSC) and a Grid-side converter (GSC).The power converter controls the active and reactive power flow, and the DC voltage of the DC-link capacitor between the DFIG wind turbine and the grid by feeding the pulse width modules (PWM) to the converters (Seyedi, 2009). In addition an crowbar is implemented to pervent short circuit in the wind energy system that result in high current and high voltage.The RSC converter opertaes at the slip frequency that depends on the rotor speed, and controls the flux of the DFIG wind turbine. The power rating of the RSC is determined according to the maximum active and reactive power control capability. The RSC can be simplified as a current-controlled volatge sources converter. The GSC operates at a network frequency and controls the voltage and current level in the DC-link circuit. It is used to regulate the voltage of One of the important requiements for wind power plant is provide fault ride-thorugh capabilities. This means that the wind power plant must withstand voltage dips to certain percentage of the nominal voltage and for a specific duration. In other word wind farm must not be disconnected from the grid during a fault or short circuit.

Result

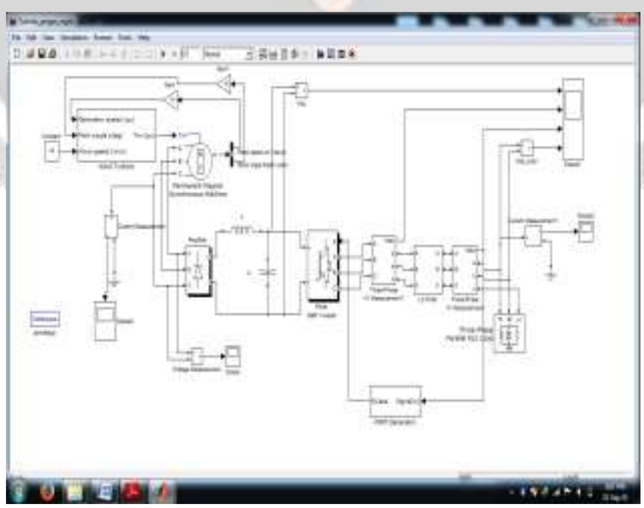

Fig .6. Wind turbine power inverter Block

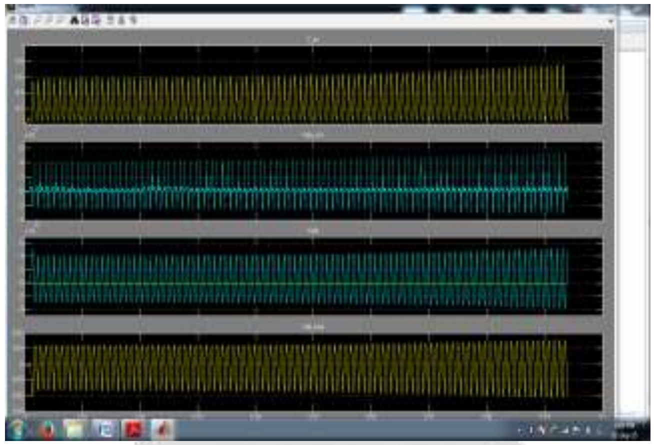

Fig .7. Wind turbine power inverter waveform.

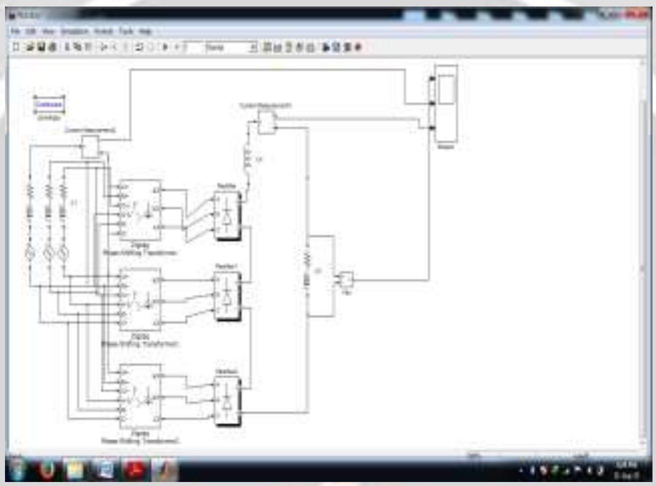

Fig.8. 12 level inverter Block

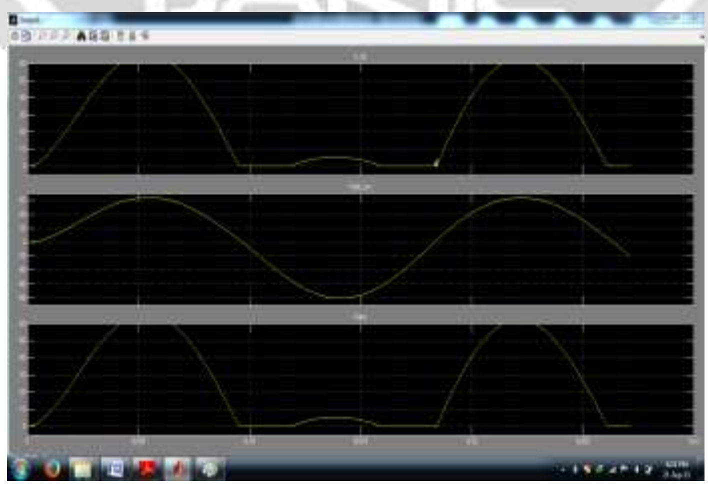

Fig.9. **12 level inverter inverter waveform.**

Conclusion

This thesis has demonstrated the state of the art of multilevel power inverter technology. Fundamental multilevel converter structures and modulation paradigms including the pros and cons of each technique have been discussed. Most of the thesis focus has addressed modern and more practical industrial applications of multilevel inverters. It should be noted that this thesis could not cover all multilevel power inverter related applications; however the basic principles of different multilevel converters have been discussed methodically. The main objective of this thesis is to provide a general notion about the multilevel power converters and various modulation strategies mainly PWM techniques and their applications. We deduced possible switching states in six level diode clamped and flying capacitor Inverters the general concept of multilevel power conversion was introduced more than twenty years ago. However, most of the

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