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Design and Implementation of a 15-Level Inverter with Facts Capability for Distributed Energy Systems

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Abstract: *In this paper a new Multilevel Inverter with Flexible AC Transmission System (FACTS) capability is presented. The main objective is to control the output voltage and reduce the harmonics distortion at the output by increasing the number of levels in the modular multilevel inverter. By using the proposed inverter for small to medium size wind application will eliminate the capacitor banks as well as FACTS device to control the power factor of the distribution line. In this paper is a new way to increase the penetration of renewable energy system into distribution systems.*

In proposed technique A 15-level inverter with FACTS capability for distributed energy systems is proposed to improve the efficiency and reduce the harmonics such as Total Harmonics distortion (THD) and Electromagnetic Interference is reduced.

The simulations for a 15-level inverter have been done in MATLAB/Simulink.

Keywords: *Total Harmonics Distortion (THD), Multi Level inverter (MLI), Flexible AC Transmission System (FACTS).*

I. INTRODUCTION

The necessities of increasing power quality in the past years lead to the development of inverter due to its efficiency and control methods. An inverter is a device which converts the direct current (DC) into an alternating current (AC) without changing the magnitude. The converted current may contain the required voltage and frequency by using the transformer, switching devices and control circuits.

In order to improve the quality of an inverter by performing the power conversion in small voltage steps resulted in lower harmonics. The output voltage of an AC side contains several numbers of discrete levels of equal magnitude. The harmonic content of a multilevel inverter is reduced, compared to the two level voltage waveform. This method is known as multilevel inverter. Multilevel inverters are significantly different from the ordinary inverter where only two levels are generated. The semiconductor devices are not connected in series to for one single high-voltage switch. In which each group of devices contribute to a step in the output voltage waveform. The steps are increased to obtain an almost sinusoidal waveform. The number of switches involved is increased for every level increment. Multi level power inverters employ power semiconductor switches in the inverter to select the DC voltage source to produce a staircase voltage waveform at the output of inverter. The output of a multilevel inverter is in the form of staircase waveform, so that the harmonics get reduced thereby the voltage gain get increased and the power quality increases.

The general purpose of the multilevel inverter is to synthesize a nearly sinusoidal voltage from several levels of dc voltages, typically obtained from capacitor voltage sources. As the number of level increases, the synthesized output waveform has more steps, which produce a staircase wave that approaches a desired waveform. Also as more steps added to the waveform, the harmonic distortion of

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the output waveform decreases, approaching zero as the level increases. As the number of level increases, the voltage that can be summing multiple voltage levels also increases.

Several multilevel inverter topologies are proposed over the past few years, the most popular multilevel inverters which are mostly used are Diode-clamped, Flying capacitor and the H-bridge multilevel inverter. One aspect which sets the cascaded H-bridge apart from other multilevel inverter is the capability of utilizing different DC voltages on the individual H-bridge cell which results in splitting the power conversion among high voltage low frequency and low voltage high frequency inverters. An alternate method of cascading involves series connection of two three phase inverters through the neutral point connection of the load.

An advantage of these cascading inverters is that isolated sources are not required for each phase. It should be noted that the cascaded inverter system can be considered in a different view points. Considering the cascaded inverter as one unit, it can be seen that a higher number of voltage levels are available for a given semiconductor devices. Capacitor batteries or renewable energy sources are used as DC voltage source.

II. Objective of the Thesis

The main objective of the thesis is to control the output voltage and to reduce the harmonic distortion at the output by increasing the number of levels. Moreover it is used as an interface for renewable energy resources.

It uses less number of switching devices for the certain number of output levels. The output voltage can be controlled by using a closed loop system. The higher the number of levels produces a better output voltage.

III. Methodology

The following methodology has been adopted in order to carry out the research work:

The output of the MLI is controlled and changed according to the desired level by the triggering pulse given to the gate terminal of the semi conductor switches.

There are several types of PWM modulation technique controlling the output voltage by changing the pulse from the PWM modulation technique.

The pulses from the PWM technique is obtained by comparing the carrier signal and the sampling signal. This pulse is given as a triggering pulse to the gate terminal of the power switching devices which is used to turn ON and OFF the power devices.

The multilevel inverter refers to using a converter in the inverting mode. Power can flow from DC side to AC side. Numerous industrial applications have begun to require higher power apparatus in recent years. Power-electronic inverters are becoming popular for various industrial drives applications. A multilevel inverter is a power electronic system that synthesizes a desired output voltage from several levels of dc voltages as inputs. Recently, multilevel power conversion technology has been developing the area of power electronics very rapidly with good potential for further developments. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application.

Multilevel inverters are extensively used in medium voltage levels with high-power applications. The field applications include use in laminators, pumps, conveyors, compressors, fans, blowers, and mills. Subsequently, several multilevel converter topologies have been developed. Multilevel inverter is a power electronic device built to synthesize a desired ac voltage from several levels of dc voltages. Such inverters have been received increasing attention in the past few years for high power application. A small total harmonic distortion is the most important feature of these inverters. Multilevel inverter is used in this work with proposed control circuit to control the output voltage using sinusoidal pulse width modulation (SPWM). PD-like Fuzzy I controller is used to control this system to get the required output voltage. The results gained in this work prove the validity of the proposed controller of having an output voltage with minimum distortion.

IV. Harmonic Reduction Techniques

In multilevel inverter the Fourier series is used to find the expression for output voltage. The Fourier expression for the output voltage is found because the angles are related with output voltage expression and the output voltage is quarter wave symmetry. So the Fourier series constants a0, an become zero and we have to find only bn.

$$Vo(wt) = \{a0 + \Sigma (an \cos nwt + bn \sin nwt)\} \operatorname{Sin} n\theta \qquad \ldots\ldots\ldots 4.1$$

$$N=1,2,3\ldots\ldots\ldots\ldots$$

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The output voltage expression For five level inverter is found as $Vo(wt) = \Sigma(4Vdc/n\pi)(\cos n\alpha1+\cos n\alpha2+\cos n\alpha3+\cos n\alpha4)\sin n\theta$ 4.2

N=1,2,3.....

Here the angles α1, α2, α3 and α4 are turn on angles for the switches of five level inverter. And these angles are used to reduce the harmonics which are present in output voltage. We can assume these angles to obtain symmetrical output voltage. But the calculated THD of output voltage is high for these angles. If we correctly select these angles, we can reduce THD in output voltage. For that we can use MATHCAD to find these angles.

The proposed system analyses the frequency spectrum and Voltage control. In conduction angle control the lower order harmonics are reduced. By adjusting the turn on angle to various levels, it is possible to reduce the lower order harmonics. And the efficiency, power factor is improved. The Fourier expression is also obtained for the output voltage of five-level inverter.

For five level inverter $Vo(wt)= \Sigma(4Vdc/n\pi)(\cos n\alpha1+\cos n\alpha2+\cos n\alpha3+\cos n\alpha4)\sin n\theta$ 4.3

Where Vdc is the supply dc voltage.

In the above expression there are four angles related to output voltage. So it is possible to reduce four odd harmonic because even harmonics are not present in output voltage. But our aim is to control the output voltage and reduction of harmonics. From the above expression four equations are formed and the four angles are found. If the no of levels are increased it is not easy to find the switching angles to remove particular order of harmonics. For that ELIMINATION THEORY is used. The modulation index is chosen as 0.8 for low THD.

V. Simulation Result of Asymmetric Multilevel Inverter

In this asymmetric multilevel inverter the voltage given to the dc sources are different. The level creator part produces a voltage which is positive. The output from the level creator part is given to the H-bridge part, thus the H-bridge changes the polarity of the output voltage. The frequency from the output voltage is given back to the input side by using a fuzzy logic controller. The input voltages given to the dc source are 180V, 90V, 45V, 23V. The output voltage at the level creator part is 220V and the output of the h-bridge is 240V.From the output voltage the frequency is feed back to the input by fuzzy logic controller. The THD get reduced to 3.06%.

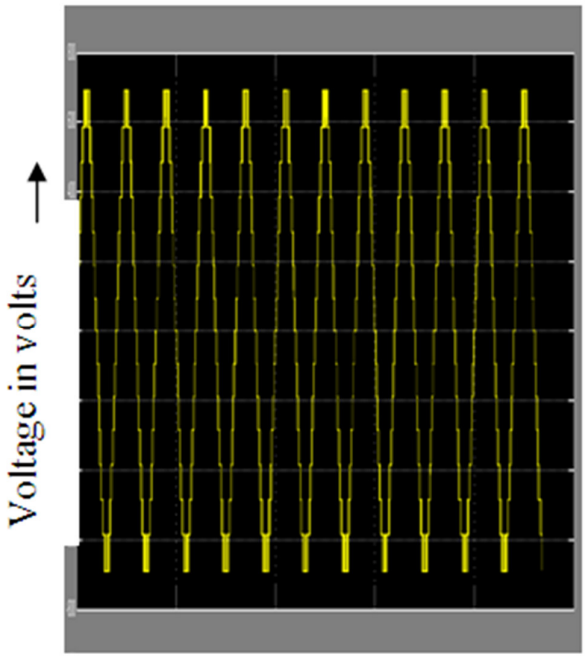

Fig. 1. Simulated output voltage of a 15-level inverter.

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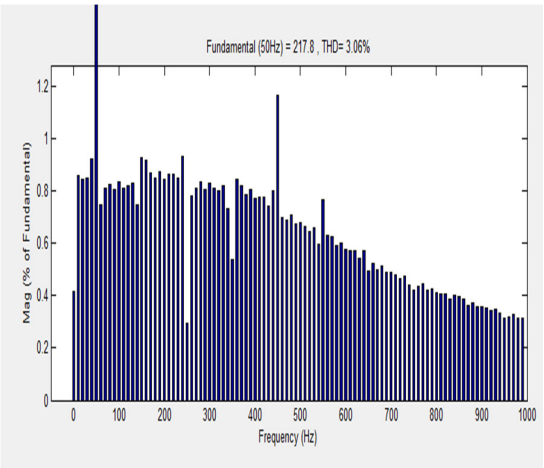

Fig. 2. Total Harmonics Distortion

VI. Conclusion

The multilevel inverter with unequal DC sources is illustrated and the gate triggering pulse is given by microcontroller in the feedback. Here the inverter power device circuit used is MOSFET device and it has the better switching frequency and gate control compared to all other semiconductor switching devices such as SCR, TRIAC etc., This fuzzy logic control technique enables us to obtain better selective harmonic reduction in the output AC voltage. Finally, we obtained the output AC voltage waveform and their frequency spectrums. Besides that, it realized better multilevel output and achieved desired results.

In this 15 level asymmetric multilevel inverter output voltage is obtained using closed loop system. The future work, the number of level is increase in the multilevel inverter in order to reduce the selective harmonics elimination and to increase the voltage gain and power quality.

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