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Study on Fault Correction of Hybrid Cascaded Multilevel Inverter Used In Renewable Energy System

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ABSTRACT: Renewable Energy sources have had increasing penetration levels for grid connected Distribution Generation in the recent years. A suitable inverter with less switching frequency and improved efficiency is required. An alternative topology for Hybrid cascaded multilevel inverter with a reconfiguration technique to eliminate fault and a modified PWM technique is to reduce switching losses is developed. The proposed topology can reduce the number of required power switches than traditional MLI and increase efficiency.

KEYWORDS: Multilevel Inverter, Hybrid Cascaded MLI, Reconfiguration Technique

I.INTRODUCTION

Electric energy power production in the 21st century has seen dramatic changes in both physical infrastructure and the control and information infrastructure. A shift is being activated from a relatively few large, concentrated generation centers. The transmission of electricity over a high voltage ac grid to a localized micro-grid has taken up pace resulting in wide utilization of renewable energy resources.

Recent trends in power semiconductor technology indicate a trade off in the selection of power devices in terms of switching frequency and voltage-sustaining capability for high power applications resulting in increased renewable energy application. Numerous topologies and modulation strategies have been introduced and studied extensively for utility and drive applications in the recent years giving emphasis to their modularity and simplicity of control [1],[2]. Multilevel inverters, entails performing power conversion in multiple voltage steps to obtain improved power quality, lower switching losses, better electromagnetic compatibility, and higher voltage capability.

A cascaded H-bridge multilevel inverter can be applied in renewable energy application to interface groups of batteries, photovoltaic or fuel cells [3],[4]. For instance, a battery or fuel cell can interface with main inverter and ultra capacitor or photovoltaic cell can also be connected to auxiliary inverter. One aspect which sets the cascaded H-bridge apart from other multilevel inverters is the capability of utilizing different dc voltages on the individual H-bridge cells, which results in splitting the power conversion amongst higher-voltage lower-frequency and lower-voltage higher-frequency inverters. Commercial buildings often have a large amount of nonlinear electronic loads, such as lighting, computers, adjustable speed drives for air conditioning etc. These may give rise to electromagnetic- compatibility and power-quality problems. These problems thus gave rise to the requirement for a cascaded inverter which can be used for both three-phase and single phase applications.

II. MULTI LEVEL INVERTER

The elementary concept of a multilevel inverter is to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. It can generate the output voltages with very low distortion, and reduce the dv/dt stresses, therefore electromagnetic compatibility (EMC) problems can be reduced .They can also draw input current with low distortion They produce smaller CM voltage, therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies. Multilevel inverters can operate at both fundamental switching frequency and high switching frequency PWM thereby reducing lower switching loss and higher efficiency.

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Their major disadvantage includes the need for greater number of power semiconductor switches; each switch requires a related gate drive circuit causing the overall system to be more expensive and complex.[2][5]

i. Multilevel inverter topologies

Plentiful multilevel inverter topologies have been proposed during the last two decades, of which three basic different major multilevel topologies studied are:

1. Cascaded H-bridges converter with separate dc sources
2. Diode clamped (neutral clamped) and
3. Flying capacitors (capacitor clamped)

A. Cascaded H-Bridges Inverter With Separate DC Sources

Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, because of the need for separate dc sources, which is the case in applications such as photovoltaic or fuel cells. They can be directly connected in series with the electrical system for static var compensation. They are also proposed for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as Single DC Sources (SDCS). Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking. Multiple DC levels and combination of fundamental frequency switching is used for some of the levels and PWM switching for part of the levels to achieve the output voltage waveform. This approach enables a wider diversity of output voltage magnitudes; however, it also results in unequal voltage and current ratings for each of the levels and loses the advantage of being able to use identical modular units for each level.

B. Diode-Clamped Multi-Level Inverter

In a Diode-clamped multilevel inverter, all of the phases share a common dc bus, which minimizes the capacitance requirements of the converter. For this reason, a back-to-back topology is not only possible but also practical for uses such as a high-voltage back-to-back inter-connection or an adjustable speed drive. The capacitors used can be pre-charged as a group and efficiency is high for fundamental frequency switching. Its major disadvantage is that real power flow is difficult for a single inverter because the intermediate dc levels will tend to overcharge or discharge without precise monitoring and control. Also the number of clamping diodes required is quadratically related to the number of levels, which can be cumbersome for units with a high number of levels.[2][5]

C. Flying-Capacitor Multilevel Inverter

The structure of this inverter is similar to that of the diode-clamped inverter except that instead of using clamping diodes, the inverter uses capacitors in their place. This topology has a ladder structure of dc side capacitors, where the voltage on each capacitor differs from that of the next capacitor. The voltage increment between two adjacent capacitor legs gives the size of the voltage steps in the output waveform. The major advantages include availability of phase redundancies for balancing the voltage levels of the capacitors. Real and reactive power flow can be controlled. A large number of capacitors enable the inverter to ride through short duration outages and deep voltage sags. Its disadvantages include the fact that control is complicated to track the voltage levels for all of the capacitors. Also, precharging all of the capacitors to the same voltage level and start up are complex. Their switching utilization and efficiency are poor for real power transmission. The large numbers of capacitors are both more expensive and bulky than clamping diodes in multilevel diode clamped converters. Packaging is also more difficult in inverters with a high number of levels.

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ii .Multilevel inverter control strategies

Abundant modulation techniques and control paradigms have been developed for multilevel inverters such as:

1. Sinusoidal Pulse Width Modulation (SPWM)
2. Selective Harmonic Elimination (SHE-PWM)
3. Space Vector Modulation (SVM) [2][5]

A. Sinusoidal Pulse Width Modulation (SPWM)

The advent of the multilevel converter PWM modulation methodologies can be classified according to switching frequency. Several multicarrier techniques have been developed to reduce the distortion in multilevel inverters, based on the classical SPWM with triangular carriers. Some methods use carrier disposition and others use phase shifting of multiple carrier signals. A number of n-cascaded cells in one phase with their carriers shifted by an angle and using the same control voltage produce a load voltage with the smallest distortion. The smallest distortion is obtained when the carriers are shifted by an angle of $\theta c = 360^\circ/3 = 120^\circ$. An advantageous feature of multilevel SPWM is that the effective switching frequency of the load voltage is times the switching frequency of each cell, as determined by its carrier signal. This property allows a reduction in the switching frequency of each cell, thus reducing the switching losses.

B. Selective Harmonic Elimination (SHE-PWM)

The selective harmonic elimination method is also called fundamental switching frequency method based on the harmonic elimination theory. For fundamental switching frequency method, the number of switching angles is equal to the number of dc sources. However, for the virtual stage PWM method, the number of switching angles is not equal to the number of dc voltages. In order to achieve a wide range of modulation indexes with minimized THD for the synthesized waveforms, a generalized selective harmonic modulation method was proposed, which is called virtual stage PWM .The virtual stage PWM is a combination of unipolar programmed PWM and the fundamental frequency switching scheme. When unipolar programmed PWM is employed on a multilevel converter, typically one dc voltage is involved, where the switches connected to the dc voltage are switched "on" and "off" several times per fundamental cycle. The switching pattern decides what the output voltage waveform looks like. The major difficulty for selective harmonic elimination methods, including the fundamental switching frequency method and the virtual stage PWM method, is to solve the transcendental equation for switching angles.

C. Multilevel Space Vector PWM

Vector diagrams are universal regardless of the type of multilevel inverter. The adjacent three vectors can synthesize a desired voltage vector by computing the duty cycle (T_j ,T_j+1, and T_j+2) for each vector

$$\frac{T_j V_j + T_j + 1\ V_j + 1 + T_j + 2\ V_j + 2}{T}$$

space-vector PWM methods generally have the following features: good utilization of dc-link voltage, low current ripple, and relatively easy hardware implementation by a Digital Signal Processor (DSP). These features make it suitable for high-voltage high-power applications to keep the number of eliminated harmonics at a constant level, all switching angles must be less than . However, if the switching angles do not satisfy the condition, this scheme no longer exists. As a result, this modulation strategy basically provides a narrow range of modulation index, which is its main disadvantage.

III. PROPOSED METHOD FOR STUDY

The main inverter used in the proposed HMI refers to the six-switch three phase inverter, and the auxiliary inverter refers to the four-switch H-bridge inverter. Since low switching losses during PWM operation is required, the

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main inverter will operate in square wave mode, and the auxiliary inverter will operate in PWM mode. A PIC single chip incorporated with a CPLD is used to generate the PWM signals for the proposed HMI.[6][7]

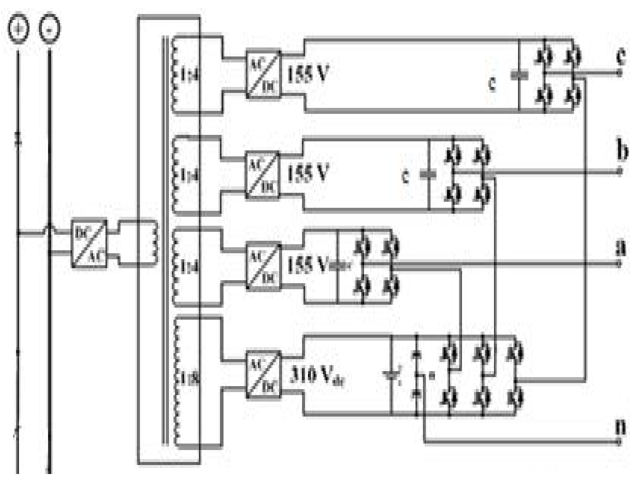

Fig no.1 Proposed cascaded Hybrid Multilevel inverter

RECONFIGURATION TECHNIQUE FOR FAULT CONDITIONS IN AUXILIARY INVERTER

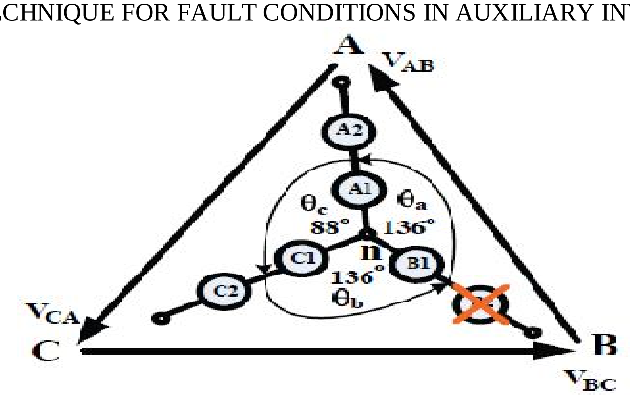

Fig no.5 The "neutral shift method for reconfiguration technique

During fault conditions, a combination of module bypass with Neutral Shift [8] is used to enhance the reliability of a modular medium-voltage drive, by utilizing the redundancy inherent in the drive. The Neutral Shift control method is used to maximize the available voltage after bypass. It increases the number of module failures that can be tolerated and thus improves the overall drive reliability. The essence [5] of the neutral shift technique is the adjustment of neutral point of three-phase wye-connection system as shown in the Figure 3.2. The line to neutral voltages (V_{an}, V_{bn}, V_{cn}) are not out of phase with each other by 120˚ ; however, the line to line voltages (V_{ab}, V_{bc}, V_{ca}) are balanced even though the auxiliary power cell on phase b is malfunctioning. [5],[2].

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FAULT TOPOLOGY FOR MAIN INVERTER

The use of multiple single-phase or cascaded inverters provides the potential for fault tolerance due to single switch open and single switch short-circuit faults. A potential isolating device inserted in series with each output phase can isolate the faulted phase from the system. This configuration of the cascaded converter is capable of being fault tolerant to single switch short-circuits, single switch open-circuits, and phase-leg open-circuits. However this configuration would result in increased inverter losses during normal operation due to the series switch [9]. Nether less the amount of reduction of the rated power and waveform quality that can be tolerated depends upon the HIM applications.

IV. CONCLUSION

A hybrid cascaded multilevel inverter can be used to interface a group of cells (batteries, photovoltaic etc.).A modified PWM technique [3] is developed to reduce switching losses and the number of required power switches and thus enhance the dc to ac conversion of the system. From the experimental efficiency evaluations and simulation results it is evident that the switching losses of hybrid multilevel inverters are much less compared to traditional, conventional multilevel inverters. 97.33% inverter efficiency has been achieved by the hybrid cascaded multilevel under study. In order to improve system reliability at fault conditions, a possible reconfiguration technique is also proposed.

REFERENCES

[1] S. Daher, J. Schmid, F. L. M. Antunes, ."Multilevel Inverter Topologies for Stand-Alone PV Systems,." IEEE Trans. on Industry Electronics, vol. 55, no. 7, pp. 2703-2711, July 2008

[2] José Rodríguez, Senior Member, IEEE, Jih-Sheng Lai, Senior Member, IEEE, and Fang Zheng Peng, Senior Member, IEEE ,
"Multilevel Inverters: A Survey of Topologies, Controls, and Applications", IEEE transactions on industrial electronics, vol. 49, no. 4, august 2002

[3] Madhav D.Manjrekar, student member IEEE,Peter K.Steimer ,member IEEE and Thomas A.Lipo, Fellow, IEEE, "Hybrid Multilevel Power conversion system: A competitive solution for High-Power Applications", IEEE transactions on industrial electronics, vol. 36, no. 3, May/June 2000

[4] N. Praisuwanna, S. Khomfoi, "A Hybrid Cascaded Multilevel Inverter," Proceedings of the 2010 Electrical Engineering/Electronics, Computer, Telecommunications, and Information Technology, Changmai, pp. 1041-1044 May 19-21, 2010

[5] Surin Khomfoi and Leon M. Tolbert, Multilevel power converters, editor- Muhammad H. Rashid, Power electronics hand book 2nd edition, Academic Press, pg(s):450-480,2007

[6] Khomfoi, S.; Praisuwanna, N.; Tolbert, L.M. , "A Hybrid Cascaded Multilevel Inverter Application for Renewable Energy Resources Including a Reconfiguration Technique", Energy Conversion Congress and Exposition (ECCE), Page(s): 3998 - 4005 , 2010

[7] Haiwen Liu, Leo M. Tolbert, Surin Khomfoi, Burak Ozpineci, Zhong Du, "Hybrid cascaded Multilevel Inverter with PWM control method," Power Electronics Specialists Conference (PESC), IEEE Page(s): 162 – 166, 2008

[8] D. Eaton, J. Rama, P. W. Hammond, ."Neutral Shift,." IEEE Industry Applications Magazine, pp. 40-49, Nov./Dec. 2003

[9] B. A. Welchko, T. A. Lipo, T. M. Jahns, S. E. Schulz, ."Fault Tolerant Three-Phase AC Motor Drive Topologies: A Comparison of Features, Cost, Limitations,." IEEE Transactions on Power Electronics, vol. 19,no. 4, pp. 1108-1116, Jul. 2004