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Comprehensive Review on Control Strategies and Topologies of Multi Level Inverter System

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ABSTRACT

In recent decades, multi-level inverters have attracted high-performance and medium voltage energy control for academia and industry. Further, the multi-level concept is used to synthesise the harmonic distortion on the output wave form without reducing the inverter power output. The multi-level concept is used for reducing harmonic distortion in the output waveform. The following topologies are presented: diode clamped inverters (neutral point clamped), capacitor clamped (flying condenser), cascaded multi-levels (dc source, etc.) and the most suitable methods of modulation developed for this category of converters: multi-level, selective harmonic elimination and space m vectors. This paper provides a series of different topologies.For 20 years, multi-level inverters have been gaining high popularity in research teams and in the development of high and medium voltage applications for industrial applications. In addition, multi-level inverters can produce switched waveforms with reduced harmonic slopes compared to a traditional converter. Multi-level inverters have recently increased interest in their ability to produce high quality wave forms at lower frequencies; the multilevel topology used in dynamic restaurant voltages decreases the harmonic distortion of the output waveform without losses of output of the inverter. This paper explores the most common topologies by incorporating control techniques for multi-level inverters, making their implementations versatile in many industrial areas in some power applications.

Keywords—Diode Clamped Inverter, Capacitor Clamped Inverter, Cascade H-Bridge Inverter, Modulation Technique.

1.Introduction

In the medium and high voltage energy industry, multi-level inverters have become common over recent years. A multi-level converter system will widely communicate with renewable power sources, such as fuel cells, solar photovoltaics, and wind [1]. Waveforms are synthesized from various voltage levels produced by insulated DC sources or a condenser bank, the fundamental principle for multi-level converters. The definition comes from Baker's introduction of converter topology[2]. In recent decades , a large number of multi-level converter topologies were proposed. Easy modulation schemes and new topologies of converters are also invented. This analysis of literature has been divided into four parts. The first is the literature review, which covers the three multi-level converter topologies: the Neutral Camped Converter, the Cascade H-Bridge and the Flying Converter. The second section addresses modulation techniques including the modulation of vector vector pulse width and sinusoidal pulse width (SPWM). Finally, multi-level converters implementation in the industry

In the last few years , various industries have begun to demand higher power devices, including renewable energy interface systems and medium-voltage industrial motor drive systems[3]. Some medium-voltage motor drives and utilities need medium and megawatt levels of electricity. A multi-story power conversion structure was thus implemented as alternative in high-power and medium-voltage situations. Many multi-story converter topologies were then created. In order to achieve a middle voltage grid only one power semi-conductor switch is not connected. In addition to achieving high levels of electricity, a multifunctional converter also allows the use of renewables. With the three-level converter the word multilevel began. Compared with traditional two-stage topology, 3-stage inverter advantages:

- Voltage is one half of the DC source voltage on the switches;
- For equivalent switching losses, the switching frequency may be reduced;
- The higher output current harmonics are decreased with the same frequency of switching.

During the last two decades, various multi-level converter topologies were proposed. Moreover, the literature has included three related major multi-level converter structures: cascaded H-bridges with separate dc sources and diode clamping (neutral clamping). In addition, abundant methods of modulation were established.Figure.1 displays a diagram of the one-phase phase-legged inverters of varying degrees, representing an ideal switch with different positions for the operation of power semiconductors. In relation to the negative terminal of the condenser a two-level, inverter produces an output voltage with two levels although three-level inverters produce three voltages, the most attractive features are as follows.

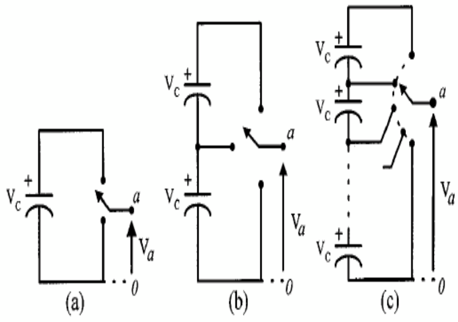

Figure.1:One Phase Leg of An Inverter With (A) Two Levels,(B)Three Levels, And(C)N Levels.

- They can produce very low and lower output voltages
- You draw very low input current distortion.
- It provides smaller common mode (CM) voltage, minimizing engine loads. CM voltages can also be removed with sophisticated modulation methods.
- The switching frequency may be lower.

II. RELATED WORKS

J.A. et al. A. [1] 99,5% effective seven-level hybrid active neutral clamping point inverter, all-silicon triphase. [1]. In this post, he addresses the newest standard for ultra-efficient power-intensive converters: a 3,4 kW / dm3 (55,8 W / in3), a 3-3-3-μm all-Silicon inverter with an efficiency of 99,35 percent. This is why another conventional FCC technique is adopted. The advantage is that by using the DC-link midpoint connexion the number of FC units is halved. Because the condensers have to be connected in number, the valued DC voltage can be easily accessed on the hardware and the front end of the ANPC level has an appraised switch which is almost the DC bus voltage switch at the grid frequency on the front end.

Q. et al .[2] addressed the research on Fringe Trends for Fringe Projection Profilometry with Message Passing Based Assessment Maximisation. In this essay , the author explores how to use the high correlation of unknown surfaces of objects to advance the presentation of FPP. The height of the surface of the body is called a Gaussian random variable, and the correlation is modelled by the first order AR model with unspecified model constants. The matter has been placed in the EM system, which is called a latent variable in height.

S. From Caro et al [3] introduced a six-level photovoltaic asymmetric hybrid inverter with internal MPPT capability. The author analyses the asymmetric photovoltaic multi-level hybrid inverter proposed in this article for medium-voltage networked photovoltaic power stations. By using the expected technique and changing the DC input voltage to achieve MPPT in case the main NPC inverter can efficiently and completely control the active power flow in cascade. Rather, the much smaller auxiliary TL1 controls the phase and amplitude of the output current as an active power philtre but even temporarily. Different kinds of power supplies may be almost fresh to better meet the different requirements of both inverters, according to the characteristics of the expected technology. The model test performed on the model scale shows that the NPC inverter input DC voltage is not balanced, even though the PV field is not radiated equally because of the application of MPPT in the cascade.

J.i. J.i. Itoh et.al[4] submitted a multi-level inverter experimental test with h-bridge clamping circuit for a tri-wire single-phase grid link. In this article , the author addresses a multi-level inverter, which is intended for 1-β-3-wire network communication, with an H-bridge clamp circuit. In order to achieve 5 stage output voltage, the planned inverter simply requires 12 gate operated switches. 16 switches are compulsory for a traditional multilevel converter with a grounded DC bus neutral stage. The proposed system 's grid control plan is drawn up. Furthermore, simulation and experimentation was deliberated and verified on the plan technique of passive modules. By using a PI controller it is possible to compensate the unstable voltage of the DC condensing unit.

X. Jiang and Jiang et al l[5] submitted a comparative analysis of grid-connected photovoltaic system multilevel inverters. In this paper , the Author analyses 3 primary (NPC, FC and CHB) techniques of 3-α 3 stage inverters suitable for photovoltaic grid-connected mid-voltage power systems. The system includes a PV array, a DC-DC converter, a 3-level inverter with a philtre, and a grid additive transformer. Multi-carrier SPWM controls for whole types of inverters were advanced using MATLAB / Simulink. The L-C philtre also guarantees the voltage and current sine waveforms. The final THD results from the recreation of these three-story inverters were expressed by FFT analysis and were shown methodically in the comparison result plate.

P. Kukadeet al.[6] submitted a cascaded Multilevel HERIC inverter to reduce leakage current in photovoltaic applications. The author studies in this article a cascade 9-level MLI based on HERIC to address the current problem of leakage in photovoltaic applications. The compact PV condensing system of the PV source can be used by separating the pv source from the ac side over the freewheeling cycle to minimise the leakage current by separating the high level frequency transition in the terminal voltage crossings. Please also note that the leakage peak is retained under the allowed value indicated in the normal. In addition, 6 switches are switched on to supply the MLI output voltage during the freewheeling phase, but only 1 switch and 1 diode are allowed. This reduces transmission and losses and improves abilities. Moreover, simulation and hardware findings show that the terminal voltage's high-frequency transition is compact and the leakage current is minimised. A three-level neutral dotted inverter control strategy has been suggested with SVPWM to provide a multi-source system. The author of this article addresses the proposed fusion device fusion modelling and control strategy based on a Permanent Magnet Synchronous Generator (PMSG), which is used in grid- and photovoltaic components for adjustable speed diesel engines and wind turbines. PMSG speed control and DC bus voltage control, active-response power control and PV power operations are the focus of the expected control strategy. The simulation results illustrate that the future control technique is appropriate and the controls are exactly similar to the reference variables. In addition, the voltage balance-centered space-vector modulation method is used to adjust the inverter to provide the power of the linear maximum area. It has other compensations, including the low frequency of switching.

M.M.G. and Lawan.et al .[8] addressed the multi-source power system for micro-grid applications focused on pv battery systems and diesel generators. Solar hybrid systems are frequently combination of diesel generators of solar energy from photovoltaic systems. The castoff connects the cavity between the current load and the actual power produced by the photovoltaic device continuously. Due to varying solar energy volumes, and partial diesel generation volumes within a given range, battery storage is typically included to optimise the solar energy contribution to the overall hybrid system performance. This device is designed for such systems, which are intended to guarantee the micro grid power supply. The fuel ingestion can be optimised by choosing an adjustable speed diesel generator. PMSG speed control, DC bus tension control and SVPWM active and reactive power control are the key areas of the proposed control strategy. The results of the simulation show that the proposed governor strategy is appropriate and the variables are similar to the benchmark. In addition, space vector variant technology is charitable for regulating the inverter, based on the composed voltage power.

Y. Walnut et al [9] addressed a multi-level inverter, with a single-phase H-Bridge Clamp Circuit, which is ideal for super-junction / SiC MOSFET connectiveness. For 1-β 3-wire mainsconnexions it is planning to use the multi-level inverter with an H-bridge clamping circuit. To achieve 5-level output voltage, the proposed inverter simply requires 12 controllable switches. 16 switches are compulsory for a traditional multilevel converter with a grounded DC bus neutral stage. The system of control was evaluated. Furthermore, simulation also calculated and validated the arithmetic design technique. Finally, the use of super interconnection MOSFET will reduce the conduction loss of the clamp circuit by 20.7 percent in comparison to the standard ANPC converter. The use of SiC MOSFET will reduce the loss of conductivity by 42.6%.

O.M. Rao et al. [10] addressed the use of traditional two level inverters to provide a multi-level inverter configuration for a 4n pole induction drive. This article proposes a multi-level inverter technology for 4nd pin motor drives, derived optimally from inductive motor stator winding systems. In this form, a 2-level conservatory inverter switches to the basic frequency. The switching loss is therefore compact. The thyristorcan also be used as a switch for low-frequency operation inverters, which is additionally suitable for use in high-power applications. In order to improve the stability of the system in case of conservative NPC or condenser clamp types the expected topology can be used in any inverter or DC power drop. The need for switching devices in the proposed setup is less than conventional topology.

III. INVERTER TOPOLOGIES

TheThe inverter is an electronic control device that changes dc power at the appropriate frequency and output voltage into accurate power. The converter which generates an output or voltage current with 2 different voltage levels is an inverter of two levels. The basic inverter deals for high switching losses, high frequency switching, and high voltage applications. This kind of reverse engine is faced with many issues, such as EMI, harmonic distortion and high switch tension. High THD is a further issue in 2 stage inverters and it is extremely difficult to synchronise semiconductor switches directly to medium and high voltage grids.Here we feel the necessary for different multi-level inverter techniques in present situations. Multilevel inverter technology with 3 stage inverter was introduced in 1975. With the aid of a high voltage level in the converter, a high power rating is possible. This reduces the converter switch rate. This type of converter generates a smooth sine waveform from different levels of dc voltage.

In production requests for high voltage and high power ratings, multi-level inverters have formed a stimulating zone. For different high power applications, it can simply be synchronised with renewable energy sources. The voltage of the DC link comes from renewable sources of electricity, from the rectifier.

The principal downside for this system involves an enormous number of semi-conductor switches and a separate gate driver circuit has been required for each switch to increase system difficulty. The whole system is extra expensive. Researchers are now working to reduce the number of switches, the difficulty of the system on the gate driver circuit

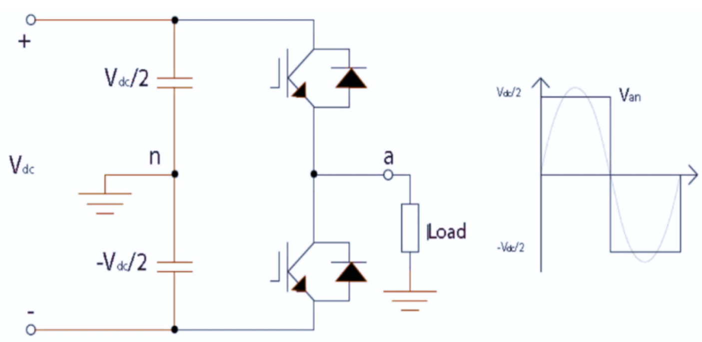

Figure 2 2-level inverter, Two-level Output Waveform without PWM

As in figure 2, an AC output voltage is produced by the basic inverter and the DC voltage is used as an input. The AC output voltage is generated using the PWM switching techniques. Numerous DC voltage phases composed of a level output waveform are integrated into the principle of multilevel inverter topology (MLI). A minimum dv / dt and harmonic distortion is present in the archived output waveform. With the increase in voltage stages, the circuit system is especially difficult. It also wants a complicated switching system.

Each leg generates three voltage stages in this inverter (Vdc /2, 0, -Vdc /2). This conversion system is identical to the regular 2-level inverter, except the clamping diodes are paired and paired between two condensers. The condensers serve as input voltages for the DC bus, each with the Vdc/2 voltage being stimulated.If the number of levels is to be increased, the relation to a new step leg may be increased. By switching nearer to the middle point, the zero voltage phase can be produced. Clamping diodes clamp to the neutral point the emitted voltage to zero. As the interrupters are more, clamping diodes and condensers are connected to the converter output to generate additional voltage stages. This results in new techniques with spaced diodes for a multi-level inverter.The multi-level inverter can be divided into two-thirds of life categories based on production: cascaded H-bridge converter with separate dc sources, multi-level inverter with diode clamps and flying condenser.

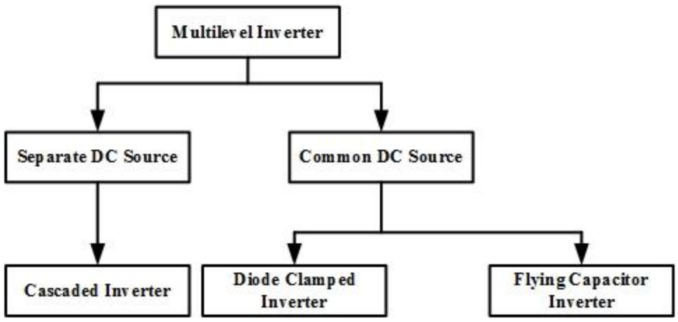

Figure 3 Multilevel Inverter Topologies

This type of Multilevel Converter reveals that it has been known to be the principal type of Multilevel Inverter, the NPC.

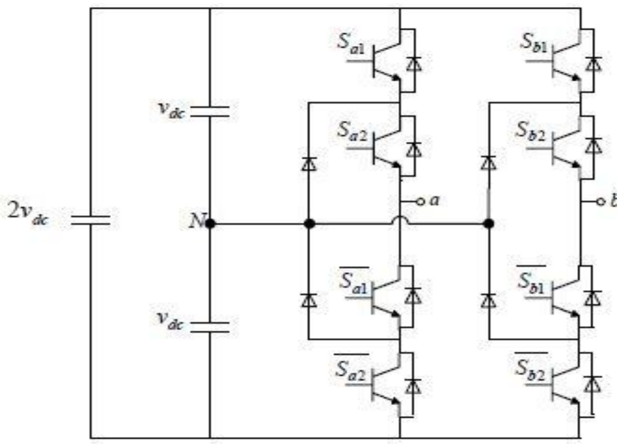

Figure 4 Neutral Point Clamped Multilevel Inverter

The 1-µf NPC power circuit is shown in Figure 4. It was fitted with two traditional two-level inverters. For the loading drive one inverter fixes above the other. In addition, the neutral mid point N was connected to 2 serial-connected diodes between the lower and higher inverters. Here condensers help the DC bus stress to be excreted in two phases. Therefore, in this situation it is inappropriate to consume an additional source of DC. The switch is just half the dc connexion voltage, Voltage transverse.The harmonics of voltage are based on the double frequency of switching. The Condenser size is limited and pre-loaded.TheConverters are used back to back and at fundamental frequency, competence is perfect.Clamping diodes are increased by growing any stage.If control and tracking is not correct, the Dc level discharges.This technique, although practical problems for high-performance converters arise. It requires high-speed clamping diodes to reverse the recovery strain. The problem with the device is a big worry because of the diode series.A Flying Capable (FC), which is calculated as a further development of the multi-level inverter system, was presented in this form of multilevel inverter. This inverter is based on the custom of condensers. It is made via the connexion of a number of condenser-clamped switching devices. Unfinished stress is transferred by condensers to electrical equipment.The replacement official in FC is the same as NPC. However, this topology of multi-level inverters does not require clamping diodes. In the process of the dismissal, these inverters benefit from balancing FC. It has the ability to monitor reactive and active power movement. Figure 4.5 demonstrates an excellent configuration for the FC multi-level inverter half-bridge technology.

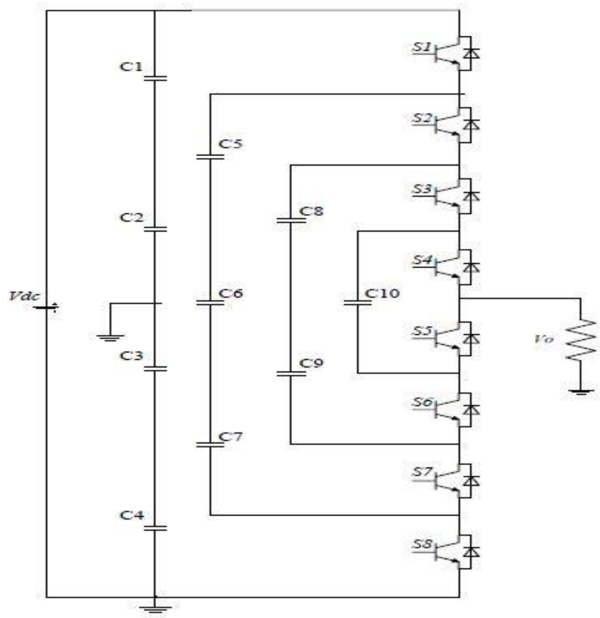

Figure 5 Flying Capacitor Multilevel Inverter

The biggest drawback of the FC inverter 's half-bridge is its voltages almost below the input DC voltage.It Avoids problems with the clamping diode. It decreases the strain of the system from dv / dt.Assistance with additional switching conditions to maintain the charge balance in condensers. It have lower capabilities in switching. The basic evident of the transformer technology, with its capability for multilevel product voltages via the source of many DC, was specified by this type of multilevel inverter

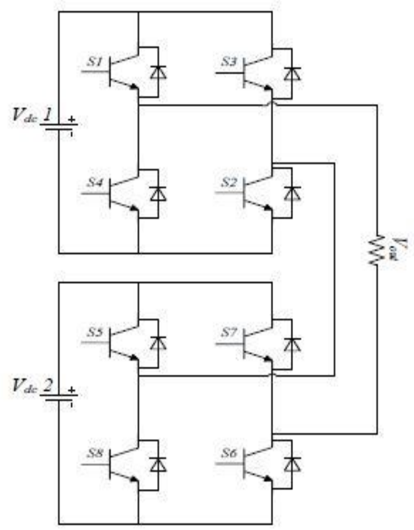

Figure 6 Cascaded H-bridge (CHB) Multilevel Inverter

Tension. This technique was related and modelled to a series of 1-3 inverters. The H-bridge circuit is equipped with eight semiconductor switches and 5 inverter levels. The DC input is connected to the H-bridge and provides 5 voltage output levels. These outputs differ with the control of 4 switches from -2Vdc to +2Vdc. This H-bridge series is related to multilevel inverter output and synchronises. The voltage steps are calculated by n=2s+1 in an H-bridge inverter. s- The number of DC sources and n- the output level of the inverter. In Figure 6, the multilevel inverter displays Cascaded H-bridge (CHB).An active clamped inverter (ANPC) is a mew type of converter that overwhelms the inadequate raw losses piece between external and internal switches that have finished positioning of power switches in place of normal diodes[10]. Figure 4.7 displays the 3-level ANPC inverter.

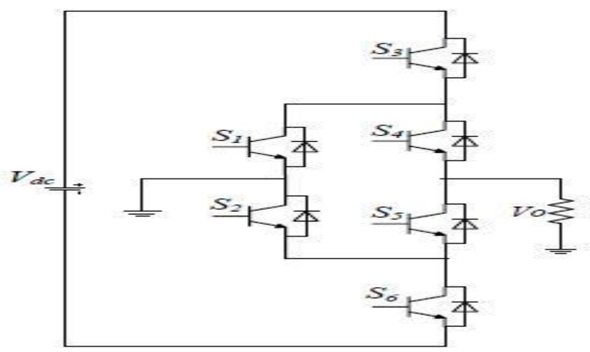

Figure 7 Active NPC Multilevel Inverter

The ANPC multilevel converter which combines techniques of the inverter of NPC and FC is shown in figure 4.8 below. This preparation achieves the amount of 2-stage inverter (n-1)/2 when n is the inverter output stage. There are 4 inverters in each segment of the technique that are used to obtain a nine stage inverter.

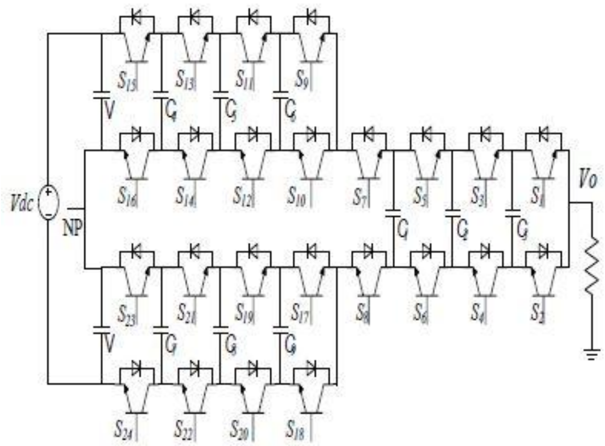

Figure 8 Active NPC Multilevel Inverter

Here 4 2-stage inverters were therefore cascaded for each portion of this technique to be provided with an inverter of nine stages. In this type of multi-level ANPC converter, there are three main parts. The 9 switches to 16 and the 4, 5, and 6 condensers are included in the main portion, but the 7 to 24 switches and the 7, 8 and 9 condensers are included in the supplementary section of this inverter. In 3 sections of this inverter, one switches to eight and one, two , three condensers are included and the inverter is connected to the load

IV CONTROL STRATERGIES

FStaircase waveform can be easily reached, but a larger philtre could produce more performance distortion to correct this. A sinusoidal PWM technique is therefore recommended in order to achieve better voltage rates of the DC-current sources based on a chopper (Fig . 1). The design of the five-story inverter is presented using small inductors, which determine simultaneously the amplitude of the wave form of the PWM output. This reduces inductor capacity, complexity of gateway circuits and complete harmonic distortion of output current[16] with the proposed multi-level topology.

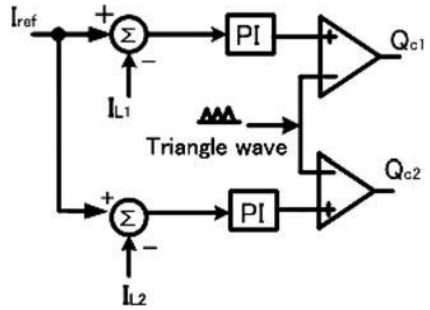

Figure 9. Controller diagram of chopper circuits

The Field Programmable Gate Array (FPGA) pulse-width modulation provides versatile sinusoidal output for single phase five-tier inverters with improved performance. The multi-level inverter performance can be adjailed on the programme stage and offer greater versatility and a new approach compared to other works listed in this paper. FPGA This is digitally generated by multi-carrier PWM of the Altera DE2 Board in terms of control technique. PWM signals are produced by the same frequency through the pulse generator block through a sinewed reference signal and two triangular carrier signals. From the diagram given for the pulse generator blockSimulations, including Sine LUT, Modulation Index, Carrier LUTs, Comparators and Pulses Logic[17], are performed.In the case of a voltage deflection, the dynamic voltage restorer (DVR) supports the load voltage, and the voltage swell compensation can be supplied with the expansion (Figure 2). In 1996, North Carolina was the first DVR built. The use of a multilevel cascaded inverter with two discontinuous SVM methods for DVR control reduces switching losses. The SVM method reduces your losses. For ML converters that improve the use of DC bus and cause lower commutation losses, SVM is the most precious PWM technology. The modulation index can be described as for an M-level inverter

$$m_a = \frac{V_m}{(m-1)E\cos\frac{1}{6}\pi} \qquad (4.1)$$

Vm is the reference voltage where E is the cell stress. Discontinuous SVM is used during sampling time to clamp down the first phase while switching the remaining two. This PWM technique allows DVR to retain the same harmonic performance, using conventional multi-level SVM technique[18], in an experimental analysis conducted on 11-kV 5-MVR DVR cascaded multilevel inverter.

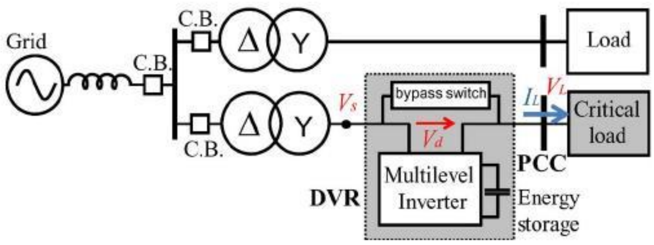

Figure 10. DVR in a distribution system

For a two-level inverter topology, two carrier-based modulation techniques allow high quality, multi-level wavelengths and power sharing. The following modulation techniques based on the carrier described:

- Continuous modulation (zero vectors symmetrical positioning);
- Discontinuous modulation (during the switching time it does not have zero vectors).

With both methods included in one PWM algorithm, the disadvantages of both techniques are eliminated and the dual two-level inverter is modulated properly[19].When it comes to processes with regular samples and multi-level vector offsets, a spectral analysis for multi-level modulation using the double technique of Fourier series become impracticeable. Nevertheless, the solution is possible using the spectral image with the single-dimensional functions of the one-dimensional Fourier series, with separate PWM waveforms and expansion lateral band base.

V. CONCLUSION

The paper discussed an analysis of the multilevel inverter topologies and their modulation technique for several scientific literatures. The multilevel inverter structure is now being used to create more and more consumer products, and multilevel inverter technologies are being researched and developed worldwide. This paper can not cover or apply to all the work in this relation, but the basic concept of various inverters has been systematically implemented. This survey study, as well as previous work on inverter topologies and their modulation technology, will be very useful to researchers in order to locate important references.Several multi-level inverter topologies and control methods have been updated, allowing engineers to employ suitable technologies to use multilevel converters for renewable energy systems with more grid integration[21]. The removal of energy system transformers achieves considerable volume and weight efficiency, decreases system complexity and power loss. A variety of commercial products are currently available on wind turbine inverters, photovoltaic centralised converters, pumped hydro storage etc. In the diversification of multilevel driven applications, an growing trend is easily observed. This trend is likely to remain stable and more implementations will be introduced with more grid codes, increased device power consumption, increasing semiconductor power creation and multi-level technology benefits [22]. To achieve a distributed generation system, multi-level converters can be efficiently used as power management system based on a range of energy sources and networks with various voltage levels

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