DESIGNING A LARGE AUTOMOTIVE ELECTRIC VEHICLE BY USING T TYPE MULTILEVEL INVERTERS

[1]Mr. Ch. Sai Charan, [2]Mrs. T. RAJESWARI

[1]PG scholar in Holy Mary Institute of Technology & Science, Bogaram (V), Medchal District, Hyderabad, India in the Dept. of Electrical & Electronics Engineering.

[2]Assistant Professor in Holy Mary Institute of Technology & Science, Bogaram (V), Medchal District, Hyderabad, India in the Dept. of Electrical & Electronics Engineering.

Abstract - The major goal of this research is to develop a bidirectional T-type multilevel inverter based on space vector pulse width modulation (SVPWM) for electric vehicle applications. A bidirectional multilayer dc-dc converter is used in this project, which is a need in electric vehicles. To balance the voltage of the T-type multilayer inverter (MLI) capacitor across a complete drive cycle or at-fault situations, the proposed one simply needs two extra power switches and a capacitor. Space vector pulse-width modulation (SVPWM) is one of the most used modulation techniques for a multilevel inverter. The SVPWM for a multilevel inverter, on the other hand, is difficult to execute. The difficulty in finding the location of the reference vector, calculating on-times, and defining and selecting switching states contributes to the complexity. Based on typical two-level SVPWM, this study presents a general SVPWM algorithm for multilayer inverters. The large electrolytic capacitors used in T-type MLI are replaced with more dependable, longer-life film capacitors in this configuration due to the high-frequency cycle-by-cycle voltage balance between CN and CP. The converter's size and weight will be reduced by 20% as a result of this. This frees up additional space in the chassis' space envelope for the EV battery, allowing it to grow in capacity. THD and line voltages are more rippled in the current system. The SVPWM approach is used to reduce these difficulties.

Key Words: (T-Type Multilevel inverter, space vector pulse width modulation (SVPWM), two-level SVPWM.

1. INTRODUCTION

To synthesizes its stepped output voltage levels, multilevel inverters often use separated dc power sources or split capacitors coupled to a single dc power source. The first type is more reliable, but it necessitates a greater number of dc power sources and power switches, such as a cascaded H-bridge multilevel inverter, as previously mentioned. Split capacitor-based MLIs, such as the neutral point clamped NPC MLI [4], flying capacitor FC MLI [5], and T-type MLI [6] [7], on the other hand, required less power components. However, because the voltage across each capacitor is based on an ideal natural balance, their voltages are vulnerable to voltage drifting, resulting in voltage imbalance operations. The three-phase inverter in the propulsion system of electric vehicles is fed by a bi-directional DC-DC converter [8] [9] [10]. It regulates the dc bus voltage to the level required to allow power to flow to the electric machine in driving mode over the designated modulation index range (mmmm). The bi-directional converter stepped the DC voltage in breaking mode (regenerative) to let power to flow in the opposite direction from the electric machine back to the utility grid or electrical storage units, as in an electric vehicle. The bi-directional converter can be built as a boost converter in motoring mode and a buck converter while braking, or vice versa, depending on the power source connected to the propulsion system.

The on-times can be obtained in one of two ways. The first method is to find the triangle and then solve three simultaneous equations for it to get the on times, as shown in [4]. The second way, as shown in [5, is to determine the triangle and then use the specific on-time equations contained in the lookup for this triangle. Both of these systems, however, become computationally costly as the number of levels rises. The works [6] and [7] offered a general approach for obtaining on-times for multilayer inverter SVPWM in the linear modulation range [8]. Celanovic and Boroyevich [6] offer a Euclidean vector system-based SVPWM technique that is rather complicated due to the utilization of multiple matrix transformations. Furthermore, neither [6] nor [7] give a systematic method for finding the switching states, nor a real-time implementation. Wei et al. [7] suggest a method that is a modified version of the system in [6]. To calculate on-times and determine switching states, this approach use the 60 coordinate system. The 60 transformation adds to the complexity because most control methods supply a voltage reference in coordinates. The SVPWM for a multilevel inverter is performed using a simple approach proposed in this paper. The technique is based on two-level SVPWM and may be built for any level with just one counter. Using the two-level approach, some studies [9]–[11] proposed multilevel SVPWM. However, these methods have some flaws that are addressed in the suggested strategy. Zhang et al. [9] offer a method for on-time calculation based on two-level simplification, in which the three-level space vector diagram is reduced into six two-level space vector diagrams.

A segregation of the three-level space vector diagram yields the locations of the centers of six virtual hexagons. To employ two-level on-time calculation, the origin is virtually relocated to one of the six centers, and the axes are rotated by 60 degrees. This strategy works effectively for three levels because only three levels require segregation. Is it possible to extend this strategy to higher levels? The on-time calculation for level n > 3 is not included in [9].

This work takes a different approach than all of the previous references and offers a general answer. It is based on a traditional Cartesian coordinate system, therefore it may be simply integrated with existing speed or torque outer control loops. The key features of the proposed plan are listed below.

1) Due to the usage of two-level SVPWM, the on-time computation is straightforward. Because the on-time calculation formulae do not change with the position of the reference vector, as in the old approach [5], no lookup tables are required.

2) The triangle where the reference vector is positioned in the space vector diagram of an n-level inverter is identified as integer j using a simple algebraic expression. The jth triangle among the (n 1)2 triangles in a sector is referred to as the triangle number j. With respect to triangle j, any switching sequence can be implemented, resulting in ease and flexibility in optimizing the switching sequence.

3) Without significantly increasing computations, the proposed approach can be applied for any n-level (n 3) inverter.

4) The proposed system is simple to implement using a commercially available motion-control DSP or microcontroller, which typically only supports two-level modulation. The technique is described in detail for a three-level inverter before being generalized to any level. For three-level and five-level inverters, experimental findings are reported.

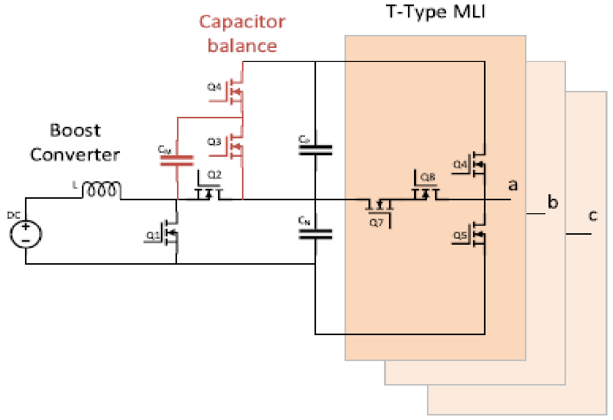

Fig.1 Proposed configuration of a multilevel bidirectional dc–dc converter connected to the T-type MLI

II. PROPOSED SCHEME

A. Proposed Method of On-Time Calculation for a Multilevel Inverter

The core idea behind SVPWM is to use discrete switching states and their on-times to compensate for the required volt-seconds. Three simultaneous equations are traditionally solved to calculate the on-times for a triangle of an n-level inverter.

However, a classical two-level space vector geometry can be used for on-time calculation for a multilevel SVPWM. Fig. 2 shows the space vector diagram of a two-level inverter. √ Every sector is an equilateral triangle of unity side and h(= 3/2) is the height of a sector.

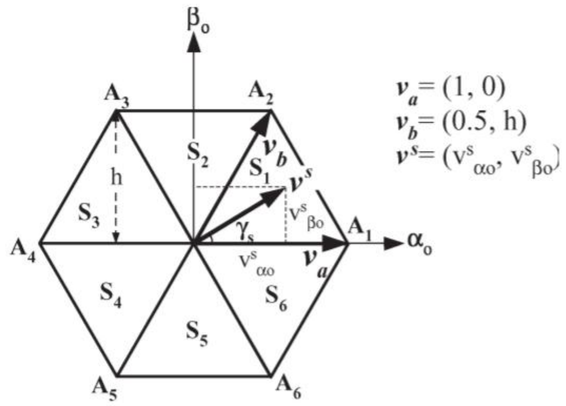

Fig. 2. Space vector diagram for two-level inverter.

On-time calculation for any of the six sectors Si, i = 1, 2,..., 6 is same, so let us consider the operation in sector 1. On-time calculation is based on the location of the reference vector within a sector. For the sector 1 in Fig. 3, the volt-second balance is given by

$$v^s T_s = v_a t_a + v_b t_b$$

Time balance is given by

$$T_s = t_a + t_b + t_o.$$

Resolving (1) along the αo − βo axis, we obtain.

$$v^s_{\alpha o} T_s = t_a + 0.5 t_b$$
$$v^s_{\beta o} T_s = h t_b.$$

Solving (2)–(4), we obtain the following equations for the calculation of the on-times:

$$t_a = T_s \left[v^s_{\alpha o} - \frac{v^s_{\beta o}}{2h} \right]$$

$$t_b = T_s \left[\frac{v^s_{\beta o}}{h} \right]$$

$$t_o = T_s - t_a - t_b.$$

Fig. 3illustrates the proposed method of the on-time calculation for a three-level inverter. Each sector of a three-level inverter can be split into four triangles j , where j = 0, 1, 2, 3. To simplify the on-time calculation, these triangles can be categorized into two types; type 1 and type 2. A triangle of type 1 has its base side at the bottom, as shown in Fig. 3(b). Triangles 0, 1, and 3 are of type 1. A triangle of type 2 has its base side at the top, as shown in Fig. 3(d). Triangle 2 is of type 2.

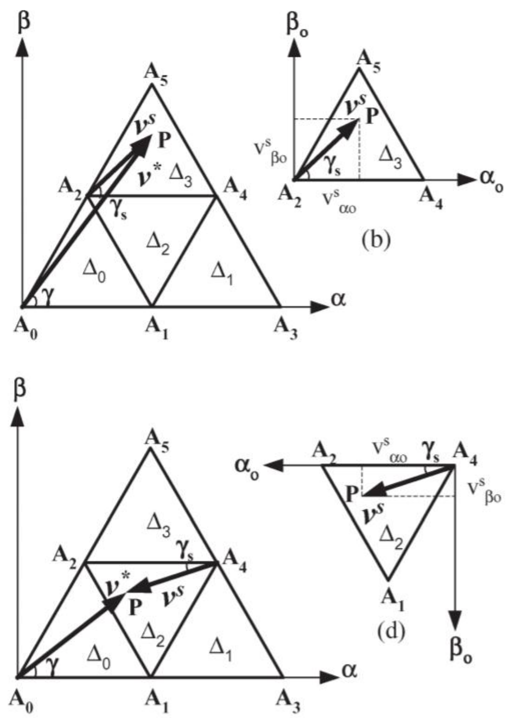

Fig3. Space vector diagram—virtual two-level from three-level.

Let us assume that the side of a triangle is 1(unity) and h(= √3/2) is the height of the triangle. In Fig. 4(a), v∗ is the reference vector of magnitude |v∗| at an angle of γ with the α-axis. We define a small vector vs, which describes the same point in shifted system (αo, βo) [see Fig. 4(b) and (d)]. It makes γs angle with the αo axis. The volt-seconds required to approximate the small vector vs in the shifted system (αo, βo) should be equal to those required for the actual vector v∗ in the original system (α, β). Hence, we can obtain the on-times for any reference vector by finding the on-times of the respective small vector vs.

To achieve the volt-seconds for any reference vector in a sector of a three-level inverter, we have to identify the triangle in which the required reference is located and then find (vs αo, vs βo). The on-time calculations can be performed using the geometry shown in Fig. 3(b) or (d), which would result in the same on-time equations as those for a classical two-level SVPWM (5)–(7). A triangle of type 1 is similar to a sector 1 of a virtual twolevel inverter.

For example; In Fig. 3(a), triangle 3 can be assumed similar to sector 1 of a two-level inverter if A2 is taken as zero vector of the virtual two-level sector as shown in Fig. 3(b). Vector A2P defines the small vector vs(vs αo, vs βo). On-times ta (tA4), tb (tA5), and to (tA2) are calculated by using (5)–(7), where the multiplication operations are required only for (5) and (6). A triangle of type 2 is similar to a sector 4 of a virtual two-level inverter. For example; In Fig. 3(c), triangle 2 can be considered similar to sector 4 of a two-level inverter if A4 is assumed to be zero vector [see Fig. 4(d)]. In this example, A4P represents small vector vs(vs αo, vs βo). On-times ta (tA2), tb (tA1), and to (tA4) are calculated by using (5)–(7).

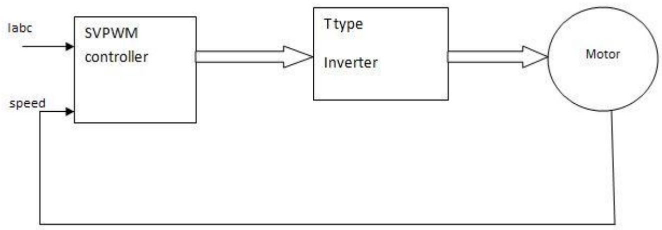

Fig. 4. Block diagram of SVPWM control

Since the triangles within any sector of an n-level inverter are analogous to a sector of two-level inverter, the idea can be extended to any level. Thus, multilevel on-time calculation problem is converted to a two-level on-time calculation problem. The on-times ta, tb, and to are a function of (vs αo, vs βo) for any triangle, using (5)–(7). Therefore, the on-time calculation for one triangle can also be used for any other triangle.

Block-Diagram Explanation of the Scheme Block diagram in Fig. 5 gives an overview of the proposed method. It consists of two basic units, namely primary unit (PU) and secondary unit (SU), respectively. The PU consists of a preprocessing unit and two-level SVPWM unit. The PU is basically a DSP or microcontroller. The preprocessing unit does two main tasks: 1) determination of small vector vs coordinates (vs αo, vs βo) and 2) determination of the sector Si and the triangle j of the small vector vs. Two-level SVPWM unit obtains the on-times to, ta, and tb by using (5)–(7). The SU is basically a mapping unit and uses memory. It fires the three-phase inverter's pre-stored switching sequence based on sector Si, triangle j for the on-times obtained from the PU. A vertex of any triangle can have many redundancies for a multilayer inverter (two or more possible switching states). A switching sequence for a triangle is created by combining the most appropriate switching states from all potential switching states at the vertices. With respect to the triangle and sector number, the resulting switching sequence is mapped. The on-times collected from the PU are then used to fire the switching sequence. Because the suggested technique considers the triangle to be the fundamental unit and the mapping eliminates redundancies, any suitable vertex can be chosen as the zero vector. Redundancies at other vertices are also used in this process. The order in which the on-times ta, tb, and to must be employed is determined by the order in which the switching states are selected. As a result, any redundancy for any vertex of the triangle can be used by the suggested technique. In contrast, when the two-level hexagon is employed to simulate two-level modulation, just two zero vector redundancies are considered. As a result, at a higher level, where middle vectors have more redundancy, such an approach will be ineffective.

III. Results

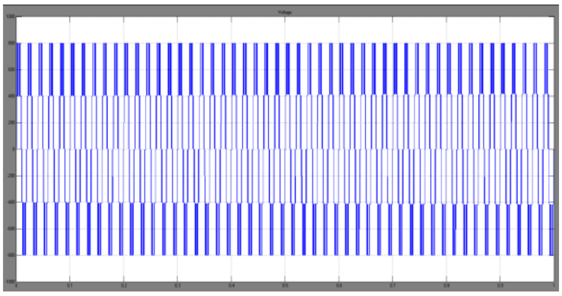

Fig. 5. single-phase line-to-line output voltage.

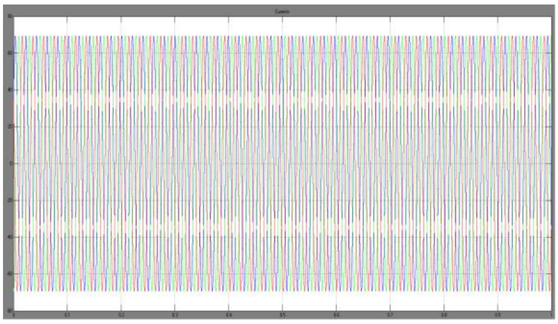

Fig. 6. Inverter currents

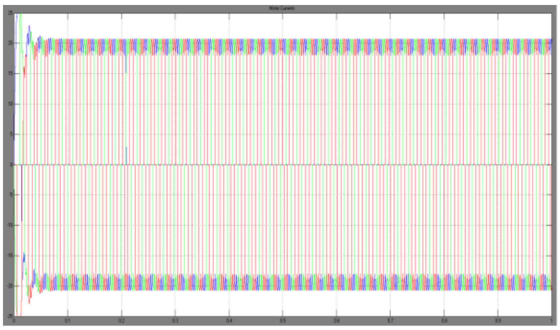

Fig. 7. Motor current in regenerative mode

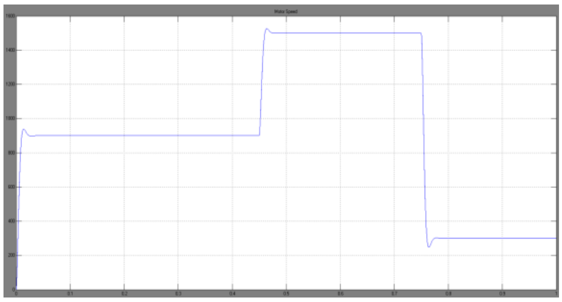

Fig8. Motor Speed varies from 900rpm to 1500rpm at t=0.45 sec and again drops to 300rpm at t= 0.75s.

As shown in generalized multilevel inverter configuration with the SVPWM technique it controls the motor THDs and the inverter switching pulse.

Conclusion

This research describes a new integration of a modified bi-directional dc-dc multilevel converter with a five-level T-type multilevel inverter for electric car applications. In comparison to a traditional voltage source inverter, the T-type MLI uses more power switches. It uses power switches with half the peak inverse voltage to provide a greater variety of output voltage levels. A simple SVPWM algorithm based on a regular two-level inverter has been presented for a multilevel inverter. Level has no effect on the computations. A commercially available motion-control DSP or microcontroller, which generally only supports two-level modulation, can simply implement the proposed technique. The suggested technique has the benefit over previous approaches in that it can be employed with an existing torque or speed control technique based on two-level geometry. Because such systems give a voltage reference in coordinates, the suggested method makes extensive use of two-level calculations and may be applied to any n-level inverter. Furthermore, the peak inverse voltage of all power switches and the rated voltage of all capacitors are both limited to half of the peak ac output voltage, reducing voltage stress, and allowing higher efficiency power switches in the dc-dc side, similar to those in the T-type MLI side, to be implemented.

REFERENCES

[1] S. Kouro, M. Malinowski, K. Gopakumar, J. Pou, L. G. Franquelo, B. Wu and e. al., "Recent Advances and Industrial Applications of Multilevel Converters," IEEE Transactions on Industrial Electronics, vol. 57, no. 8, pp. 2553-2580, Aug. 2010.

[2] J. Rodriguez, J.-S. Lai and F. Z. Peng, "Multilevel inverters: a survey of topologies, controls, and applications," IEEE Transactions on Industrial Electronics, vol. 49, no. 4, pp. 724-738, Aug 2002.

[3] M. Z. Youssef, K. Woronowicz, K. Aditya, N. A. Azeez and S. S. Williamson, "Design and Development of an Efficient Multilevel DC/AC Traction Inverter for Railway Transportation Electrification," IEEE Transactions on Power Electronics, vol. 31, no. 4, pp. 3036-3042, April 2016.

[4] T. Ishida, T. Miyamoto, T. Oota, K. Matsuse, K. Sasagawa, and L. Huang, "A control strategy for a five-level double converter with adjustable dc link voltage," in Proc. Ind. Appl. Conf., Oct. 2002, vol. 1, pp. 530–536.

[5] S. K. Mondal, J. O. P. Pinto, and B. K. Bose, "A neural-networkbased space-vector pwm controller for a three-level voltage-fed inverter induction motor drive," IEEE Trans. Power Electron., vol. 38, no. 3, pp. 660–669, May/Jun. 2002.

[6] N. Celanovic and D. Boroyevich, "A fast space vector modulation algorithm for multilevel three phase converters," IEEE Trans. Ind. Appl., vol. 37, no. 2, pp. 637–641, Mar./Apr. 2001.

[7] S. Wei, B. Wu, F. Li, and C. Liu, "A general space vector pwm control algorithm for multilevel inverters," in Proc. 18th Annu. IEEE APEC, Feb. 2003, vol. 1, pp. 562–568.

[8] J. Holtz, W. Lotzkat, and A. M. Khambadkone, "On continuous control of pwm inverters in overmodulation range including six-step," IEEE Trans. Power Electron., vol. 8, no. 4, pp. 546–553, Oct. 1993.

[9] H. Zhang, A. Von Jouanne, S. Dai, A. K. Wallace, and F. Wang, "Multilevel inverter modulation schemes to eliminate common-mode voltages," IEEE Trans. Ind. Appl., vol. 36, no. 6, pp. 1645–1653, Nov./Dec. 2000.

[10] J. H. Seo, C. H. Choi, and D. S. Hyun, "A new simplified space-vector pwm method for three-level inverters," IEEE Trans. Power Electron., vol. 16, no. 4, pp. 545–550, Jul. 2001.

AUTHOR DETAILS':

Mr. Ch. Sai Charan received a B. Tech Degree in Electrical and Electronics Engineering from JNTUH College of Engineering Manthani, Pannur(V), Ramgiri(M), Peddapalli(D), Telangana, India, and is Studying M. Tech in Power Electronics at Holy Mary Institute of Technology and Science, Bogaram(V), Medchal (D), Hyderabad, India.

Mrs. T. RAJESWARI received the B.TECH degree in EEE from Sridevi women's engineering college, V.N.Pally, College Rd, Gandipet, Telangana, INDIA, from JNTU University and MTECH in Electrical Power Systems in Tirumala engineering college, Bogaram (v), Medchal(D), Hyderabad, Telangana, INDIA. She has 1-year industrial experience and 5 years of teaching experience. Currently pursuing Ph.D in SR University and working as an Assistant professor at Holy mary Institute of Technology and sciences, Bogaram, Medchal District, Hyderabad, Telangana, INDIA in EEE department. Her interest areas are FACTS, Computer aided power system analysis, electrical distribution systems, Power electronics etc.