Three Level Inverters with Nine Switch Topology for Electric Vehicle Applications

S. Gokul[1], M. Karthik[2], R. Nithya Devi[3] and R. Thangaraj[4]

[1, 2, 3, 4] *Assistant Professor, Department of Electrical and Electronics Engineering*
[1, 2, 3, 4] *Coimbatore Institute of Engineering and Technology, Coimbatore, Tamilnadu, India*

Abstract—*This paper presents a nine-switch 3- level inverter used as software for all-electric powered vehicle (EV) and hybrid-electric powered vehicle (HEV) motor drives. The proposed 3-level inverter is composed of a three-section-level inverter and three bi-directional strength switches. The proposed inverter overcomes a few shortcomings of 2- level inverters, including high switching frequency, excessive dv/dt and electromagnetic interference (EMI). The proposed inverter also reduces the wide variety of electricity switches from twelve to nine in comparison with conventional three-level inverters. Fewer switches lessen system value and improve system reliability. The proposed three-level inverter is suitable for low voltage applications due to the fact the voltage strain across a part of energy switches on this circuit is full of the DC bus voltage. Losses of the proposed inverter are analyzed and compared with other two inverters. The basic precept and control scheme of the proposed 3-level inverter are brought. Analytical, simulation, and experimental results display the superiority of the proposed 3-level inverter for electric vehicle applications.*

keywords — *New Topology; nine-transfer 3-level Inverter; EV Motor force.*

I. INTRODUCTION

The development of electrical automobiles (EV) and hybrid- electric powered motors (HEV) has offered many challenges to the electrical electronics project, specifically in the development of the motor traction drives. Many contemporary and future designs will incorporate the use of induction motors as the number one source for traction in electric motors [1]. Three-segment two-level inverter, referred to as six switches inverter, is widely used. This topology has the merits of low fee, without difficulty controlled and high reliability, however it also has some shortcomings which include: excessive switching frequency, excessive dv/dt and electromagnetic interference (EMI) [2, 3]. Motor damage and failure has been reported via enterprise as an end result of adjustable velocity pressure inverters excessive switching frequency PWM [4]. The main problems pronounced were “motor bearing failure” and “motor winding insulation breakdown” because of the high dv/dt. High switching frequency additionally causes excessive switching loss and EMI [5]. Those shortcomings aren't in accord with the layout requirements of EV/HEV propulsion structures [6].

To overcome those shortcomings of traditional - level inverter motor drives, a few multilevel inverters, along with traditional three-level diode-clamped inverters and cascade inverters, have been used as EV/HEV motor drives in a few literatures. Multilevel inverters have shown the prevalence over -level inverters in EV/HEV motor drive programs; however the use of a big number of energy switches in those topologies is a main downside so that you can boom the device fee, control complexity and decrease the device reliability. This paper gives a 9-transfer 3-level inverter used for EV/HEV motor drives.

The proposed inverter overcomes some shortcomings of -level inverters, inclusive of high switching frequency, high dv/dt and EMI. The proposed inverter also reduces the quantity of power switches from twelve to nine compared with conventional three-level inverters. The discount of power switches ought to lessen machine value and enhance device reliability. the novel inverter has all blessings of the conventional three-level inverters besides that the voltage stresses across a part of electricity switches are full the DC bus voltage, so it's miles suitable for low voltage applications, consisting of for electric vehicle motor drives.

This paper consists of: 1) system configuration and evaluation of the proposed 3-level inverter; 2) space vector pulse width modulation (SVPWM) 3) losses and comparison 4) simulation results 5) conclusion.

II. SYSTEM CONFIGURATION AND ANALYSIS

A. Main Circuit of 3 Level Inverter

The proposed nine-transfer 3-level inverter used as EV motor drives is proven in Fig. 1. The nine-switch three – level inverter consists of one conventional 6- switch -level inverter, 3 bidirectional switches and two dc electricity substances in collection. The bidirectional switch is includes 4 power diodes and one electricity switch. Voltage stress across the strength diodes and switches inside the bidirectional switches while they are switched off is half of the DC bus voltage, and voltage pressure across different six switches is full the DC bus voltage.

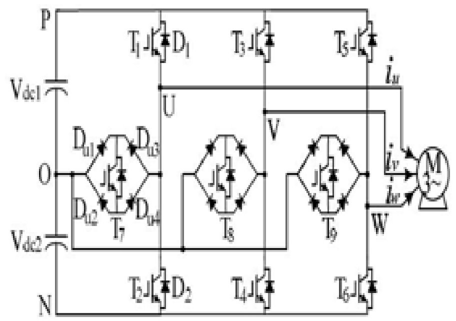

Fig 1. Proposed Nine Switch Three Level Inverter.

These traits made the proposed inverter appropriate for low voltage programs. The dc bus voltage consists of dc strength materials in series. The dc electricity resources might be batteries used for EV drives or capacitors used for HEV drives. For collection HEV, a returned-to-returned-connection of the proposed inverters can be used to pressure traction cars. The series HEV system configuration with returned-to-back-connected 9- switch three-phase inverter is proven in Fig. 2.

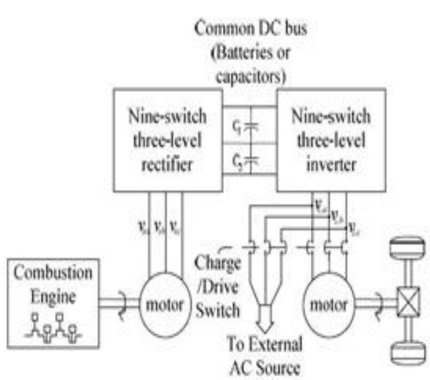

Fig 2. Series HEV System Configuration with Back-to-Back-Connected Nine-Switch Three-Level Inverter.

B. System Analysis

Every segment of the inverter ought to produce 3 exclusive voltage levels. The 3 levels are denoted with P, O and N respectively. The output terminal U is attached to P if switch T1 is became on at the same time as T2 and T7 is became off; The output terminal U is linked to N if transfer T2 is grew to become on even as T1 and T7 is became off; The output terminal U is hooked up to O if switch T7 is turned on when T1 and T2 is became off. States of the three output ranges are summarized in Table I.

TABLE I. Three Voltage Level of the Proposed Three Level Inverter

Voltage level	Output voltage	i_a	T_1	T_2	T_7	Current Path
P	$V_{dc/2}$	$i_u>0$	on	off	off	p-> T_1 ->U
		$i_u<0$	on	off	off	p <- D_1 <- U
o	0	$i_u>0$	off	off	on	O->D_{u1} -> T_7 -> D_{u4}-> U
		$i_u<0$	off	off	on	O<- D_{u2} T_7<- D_{u3} <- U
N	- $V_{dc/2}$	$i_u>0$	off	on	off	N->D_2 ->U
		$i_u<0$	off	on	off	N<- T_2<- U

As compared with two-level inverter, the proposed inverter may want to reduce dv/dt and EMI with low switching frequency. as compared with conventional three-level inverter, the principal gain of the proposed inverter is that it reduces the variety of strength switches used in the circuit from twelve to nine. The reduction of strength switches can lessen system value and increase device reliability. The switching configuration for the proposed inverter is given inside the Table.1.For one leg only one switch is on at one time.

III. SPACE VECTOR PULSE WIDTH MODULATION

So far various pulse-width modulation (PWM) strategies had been studied and a terrific lots of effects are published such as modified two-level triangular service-based modulation, selective harmonic elimination modulation approach (SHEPWM), space vector PWM (SVPWM) and some aggregate PWMs. among various modulation techniques for multilevel inverter, SVPWM is an appealing candidate due to the following deserves. It at once makes use of the control variable given by way of the control machine and identifies each switching vector as a point in complex (α, β) space. It is appropriate for virtual sign processor (DSP) implementation. The definition of the switching space vector is proven in (1).

$$V(S_a, S_b, S_c) = \frac{1}{3}V_{dc}(S_a + S_b * e^{j\frac{2\pi}{3}} + S_c * e^{-j\frac{2\pi}{3}}) \quad (1)$$

Where in Si (i=a, b, c) is switching feature. The given reference vector V_{ref} is synthesized by using space vector modulation (SVM) the usage of three switching space vectors that are nearest to the reference vectors at every sampling instantaneous. The reference vector is synthesized as (2) and (3).

$$V_{ref} = d_0V_0 + d_1V_1 + d_2V_2 \quad (2)$$

$$d_0 + d_1 + d_2 = 1 \quad (3)$$

Where d0, d1, d2 are the obligation cycles of the closest 3 switching vectors V0, V1, V2 and Vi is vector (Sa, Sb, Sc).

IV. LOSSES AND COMPARISION

Converter performance is one of the fundamental overall performance indices. Losses produced by the switching factors are commonly taken into consideration as a predominant project in the course of converter design. Voltage stresses across the switches immediately have an impact on their electricity score, as a result their length, weight and fee. Device losses include two parts: conduction losses and switching losses. To expose the efficiency of the proposed three-level inverter, following discussion takes into consideration 3 inverter topologies: three phase a 120º conduction mode, three phase 180º conduction mode and proposed nine transfer three level inverter the results are proven in Table II. The losses of conventional -level inverter are the smallest. The losses of the proposed inverter are between that of conventional two-level and three-level inverters.

TABLE II. Comparison of THD for Different Modes

MODES OF OPEERATION	THD ANALYSIS
120º Conduction Mode	40.06%
180º Conduction Mode	32.56%
Proposed Inverter	22.85%

V. SIMULATION RESULTS

The proposed three level inverter is simulated with the usage of MATLAB 2007b. The DC voltage applied here is 200 volts. The output line present day, voltage and phase voltage are shown in the Fig. 3, 4, 5 respectively. The output line contemporary is stepped via the use of suitable filter out association we will convert it into sinusoidal. The voltage pressure across the switch is reduced in this proposed inverter model.

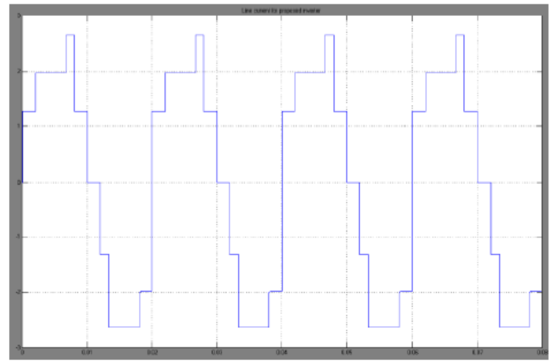

Fig3. Line Current of the Proposed Inverter.

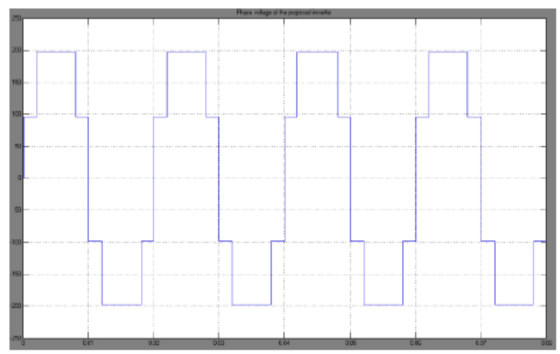

Fig 4. Line Voltage of the Proposed Inverter.

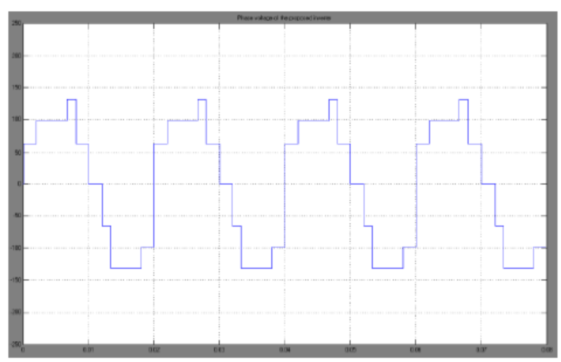

Fig 5. Phase Voltage of the Proposed Inverter.

With the aid of the use of the SVPWM method THD and electromagnetic interference is reduced.

VI. CONCLUSION

This paper gives a nine-switch 3-level inverter used as software for EV/HEV motor drives.

The proposed inverter overcomes a few shortcomings of two- level inverters, together with excessive switching frequency, excessive dv/dt. The proposed inverter also reduces the variety of energy switches from twelve to nine compared with conventional 3-level inverter. Fewer switches lower the device price and improve system reliability. Losses evaluation and assessment show that the proposed inverters losses are appropriate while current is not too high. Simulation and experimental consequences show that the proposed nine-switch three-level inverter is accurate and effective

REFERENCES

[1] J. M. Miler, A. R. Galc, "Hybrid-electric vehicle success will depend on low cost, efficient power electronics systems," *Power Conversion & Intelligent Motion (PCIM)*, Nov. 1997, pp. 22-38.

[2] Leon M. Tolbert, Fang Zheng Peng, Tim Cunnyngham, John N. Chiasson, "Charge Balance Control Schemes for Cascade Multilevel Converter in Hybrid Electric Vehicles," *IEEE Transactions on Industrial Electronics*, Vol. 49, No. 5, pp. 1058-1064, October 2002.

[3] Leon M. Tolbert, Fang Z. Peng, "Multilevel Converters for Large Electric Drives," *Applied Power Electronics Conference and Exposition, 1998. APEC '98. Conference Proceedings 1998, Thirteenth Annual*, Volume 2, 15-19 Feb. 1998 Page(s):530 - 536

[4] Leon M. Tolbert, Fang Zheng Peng, Thomas G. Habetler, "Multilevel Converters for Large Electric Drives," *IEEE Transactions on Industry Applications*, Vol. 35, No. 1, pp. 36-44, JANUARY/FEBRUARY 1999.

[5] Leon M. Tolbert, Fanf Z. Peng, Thomas G. Habetler,"Multilevel inverter for electric vehicle applications," *WPET'98*, Dearborn, Michigan, October 22-23,1998, pp. 79-84.

[6] Brian A. Welchko, and James M. Nagashima, "The Influence of Topology Selection on the Design of EV/HEV Propulsion Systems," IEEE Power Electronics Letters, Vol. 1, No. 2, pp. 36-40, JUNE 2003.