A Novel Pulse Width Modulation Scheme for T-Type Multi-level Inverter

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Abstract: In recent times, abbreviated switch calculates multilevel inverter (RSC-MLI) has become an regressing area of inquiry in power electronic converters. To ascendance these RSC-MLI topologies, different novel modulation connives are reported. Multi reference is one such changes scheme covered for different RSC topologies, such as T-type. Even so, the performance of this old scheme results in high total harmonic distortion (THD) in line voltages, when equated with the conventional level shifted pulse-width modulation planes. This observation is now in this study and the reason for its degraded THD performance has been intensely discussed. To appease this question, a modified multi-reference dual-carrier modulation technique with multiple references and two carriers is intended. To carry out this proposed modulation methods, an alternate carrier and modulation signals arrangement with various carriers and single reference is also awarded. Finally, a relative THD performance of the given and conventional modulation methods is carried out on a five-level T-type MLI and found simulation results are corroborated experimentally.

***IndexTerms*– THD, RSC_MLI, T-Type.**

I. INTRODUCTION

Multilevel inverters (MLIs) use the concept of addition of small multiple voltage levels and possess various advantages like reduction in d*v*/d*t*, electro-magnetic interference and total harmonic distortion (THD) [1, 2]. In literature, cascaded H-bridge (CHB), diode clamped and flying capacitor are the widely accepted classical MLI topologies, and are reported with various modulation strategies, such as sinusoidal pulse-width modulation (SPWM), selective harmonic elimination (SHE), third harmonic injection and space vector modulation (SVM) [3–8]. Among these conventional schemes, SPWM is very popular due to its easiness in implementation and is further classified into level shifted pulse width modulation (LSPWM) and phase shifted pulse-width modulation (PSPWM) [9]. LSPWM is sub-classified into in phase disposition (IPD), opposite phase disposition (OPD) and alternate phase disposition (APD). It is well reported that LSPWM-IPD results in better line THD performance compared with LSPWMOPD, LSPWM-APD and PSPWM [9].

In practice, MLIs are limited to lower levels, because of its increased switch count at higher levels. This increase in switch count not only turns the topology complex but also raises its overall cost. Form past two decades, there is an extreme exploration carried out to evolve newer topologies with reduced switch count (RSC). T-type is one of the recently reported RSCMLI, which gathered much attention. T-type possesses most feasible and generalised configuration with 37.5% reduction in switch count compared with classical topologies [10–12]. Extreme reduction in switch count of RSC-MLI's created diversified effects on switching states such that, most popular conventional SPWM schemes are insufficient to implement them [13, 14]. In literature, few of such RSC configurations are reported with SHE and SVM methods. However, these schemes involve complex mathematical calculations, which turn more complicated at higher levels [15].

Recently, few RSC topologies are reported with multi-carrier modulation schemes involving logical expressions. However, these logical expressions are not generalised, and vary with variation in number of levels and topological arrangement [15]. A novel multi reference modulation scheme for T-type MLI is reported, and a seven-level T-type with multi-reference modulation for grid connected systems is reported in [16, 17]. This scheme is accepted widely, due to its generalized nature which can be applicable to any RSC configuration [18–21]. However, this scheme suffers from high THD in line voltages when compared with the conventional PWM scheme. In [22], a phase shifted multi-reference The modulation scheme is reported for cascaded T-type topologies. In this method, the number of carriers is equal to the number of modules that are connected in cascade and moreover, when considering a single module its performance is identical to a conventional multi-reference modulation scheme. From the keen literature review of various multi-reference and

Multi-carrier modulation schemes reported for multiple RSC-MLI topologies, it is observed that most of these schemes either result in high THD in line voltages or suffers from the generalization of switching scheme at higher levels. This observation is clearly discussed in this paper and simple generalized modulation schemes are proposed, which obtain satisfactory line voltage THD performance on any RSC-MLI topology.

The structure of the proposal is as follows. In Section 2, performance of conventional multi-reference modulation scheme on a five-level T-type MLI is discussed and the reason for its poor THD performance is analysed. In Section 3, modifications in the

Traditional multi-reference modulation scheme to improve its THD performance are suggested and a modified multi-reference the dual-carrier modulation scheme is proposed. Also, to implement the proposed project an alternative carrier and modulating signal arrangement is presented and generalization of this scheme to higher levels is discussed with the help of a Flowchart. Performance of the proposed system is investigated on a five-level T-type topology and they're superior harmonic performance over conventional multi-reference modulation can be Observed. Section 4 presents the observational results of the advised and traditional modulation schemes on a five-level T-type MLI. Obtained simulation results are validated experimentally with dSPACE-1104 R&D control board. Finally, comparative performance of the proposed and conventional modulation schemes, for a five-level MLI, at various modulation indices is carried out.

II. CLASSIFICATION OF DIFFERENT MODULATION TECHNIQUES

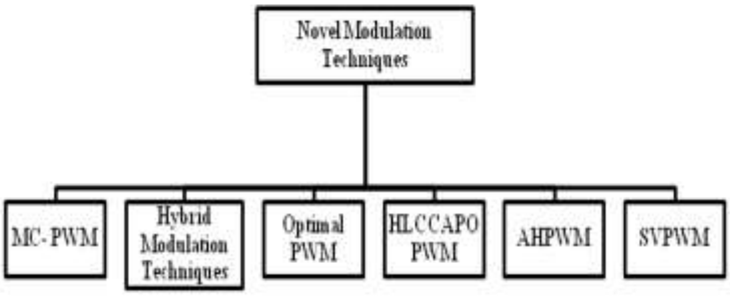

Fig. 1. Block diagram for novel modulation techniques

1. Multi carrier Pulse Width Modulation (MC-PWM).
2. Hybrid modulation techniques.
3. Synchronous pulse width modulation and higher frequency sub harmonic PWM
4. Higher and Lower Carrier Cells and Alternative Phase Opposition PWM
5. (HLCCAPOPWM)
6. Alternative hybrid PWM (AHPWM).
7. Space vector PWM (SVPWM).

These modulation proficiencies can also be employed for other multilevel inverter forms like diode clamped MLI, flying capacitor MLI and cascaded MLI. These modulation techniques are explicated in general. Some modulation proficiencies are readily applicable to especial MLI but have to be changed for some other configurations. Modulation ratios as a crucial role in all the techniques. Modulation can be over modulation or under modulation depending on modulation ratio, and accordingly, total harmonic distortion (THD) varies. While describing modulation techniques MLI topology, modulation ratio, and THD are considered as significant factors. Following definitions are to be believed for further description. Amplitude Modulation ratio (ma), determined as ma=Am/Ac, where Am is the amplitude of the reference signal and Ac is the peak-to-peak amplitude of the carrier signal. (For an N-level inverter, this ratio is fixed as ma = Am/(N-1)Ac.

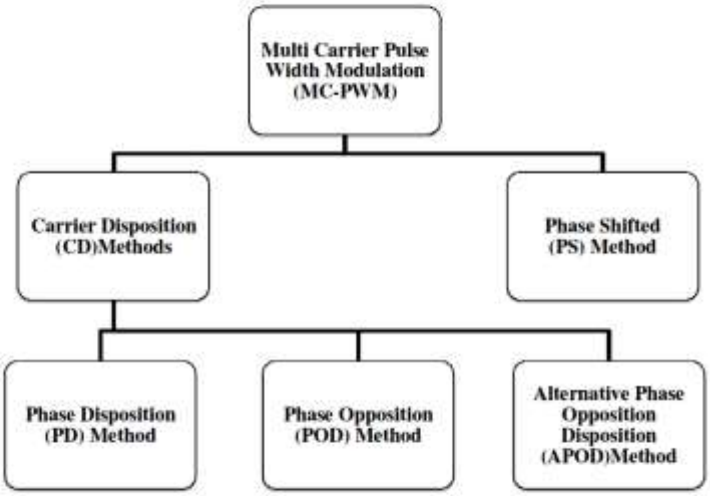

Fig.2.Multi carrier pulse width modulation

III. PROPOSED PV-STORAGE SYSTEM ARCHITECTURE

3.1 DESIGN OF PROPOSED SYSTEM

- T-type configuration

T-type topology is the congregation of bidirectional and unidirectional switches. To obtain five levels in phase voltage, four unidirectional switches (*S*1, *S*2, *S*3 and *S*4), one bidirectional switch and two dc sources are required per phase as shown in Fig. 3. Considered bidirectional switch is represented with two back-to back connect unidirectional switches (*S*5 and *S*6). The four unidirectional switches form an H-bridge and the isolated dc supplies are connected to H-bridge through the bidirectional switch. As the level increases, requirement of bidirectional switches and dc sources increases, but the switches in the H-bridge remains unaltered. To obtain '*n'* levels in phase voltage and '2*n*−1' levels in line, '4 + (*n*−3)' switches are required per phase. Here, four indicate number of switches in H-bridge and '*n*−3' indicate additional unidirectional switches required.

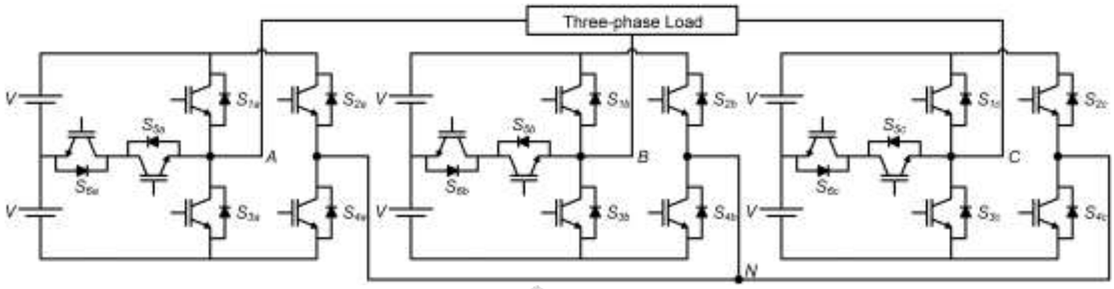

Fig. 3 Five-level T-type topology

Table 1 Operating switches to obtain respective voltage levels in each phase

Switches in conduction	Voltage level
S_5 and S_4	V
S_1 and S_4	$2V$
(S_1 and S_2) or (S_3 and S_4)	0
S_6 and S_2	$-V$
S_3 and S_2	$-2V$

IV. DIFFERENT TOPOLOGIES OF MULTI LEVEL INVERTER

Diode-clamped multilevel inverters apply to clamp diodes in arrange to bound the voltage stress of power devices in a particular power circuit. It was first aimed in the year of 1981, and it is also addressed as neutral point converter. Usually, A k stage diode clamped inverter needs (2k – 2) switching devices, (k – 1) input voltage source and (k – 1) (k– 2) diodes to operate [3, 4]. The two famous drawbacks of this type of inverter are Clamping diodes are enhanced with the enhanced of each level, and DC level will discharge when control and monitoring are not much precise. Some of the advantages over another type of inverters are back to back inverters can be used, capacitors used here are pre-charged, and at the primary frequency, the efficiency is high. This inverter is mostly applied in high voltage power drives and power compensators [5].

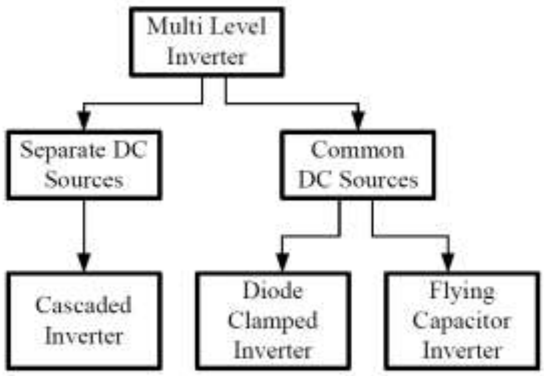

Fig.4.Types of Multi Level Inverter

The flying capacitor MLI has applied capacitors to bound the voltage alternatively of diodes. While using capacitors instead of diodes, it experiences some drawbacks, i.e., Diodes have the potentiality to block the reverse flow of voltage but here capacitors are incompetent to do it, cost of capacitors also more eminent than the diodes. The number of switches also enhances in flying capacitor MLI; it leads to poor switching efficiency. The input DC voltages are carved up by the capacitors here. The voltage over apiece capacitor and each switch is Vdc[6,7]. A k degree flying capacitor inverter with (2k – 2) switches will use (k – 1) number of capacitors to engage. The figure at a lower place shows a five-level flying capacitor multilevel inverter. The one of the best covering of this type of inverters is in Static VAR compensators for assuring the real and reactive power flow. Since of its ladder structure voltage on each capacitor is disagreeing from the next, since voltage control of all the capacitor is hard.

V. RESULTS AND DISCUSSION

T-type topology is the congregation of bidirectional and unidirectional switches. To obtain five levels in phase voltage, four unidirectional switches (*S*1, *S*2, *S*3 and *S*4), one bidirectional switch and two dc sources are required per phase as shown in Fig. 5. Considered bidirectional switch is represented with two back-to back connect unidirectional switches (*S*5 and *S*6).

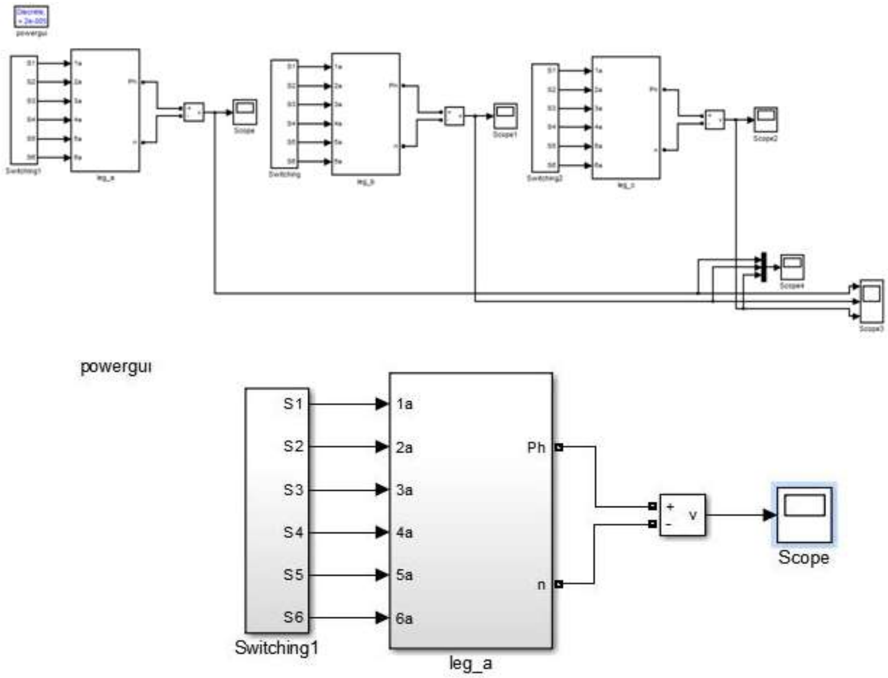

Fig.5. Simulation Diagram

The four unidirectional switches form an H-bridge and the isolated dc supplies are connected to H-bridge through the bidirectional switch. As the level increases, requirement of bidirectional switches and dc sources increases, but the switches in the H-bridge remains unaltered. To obtain ‘*n’* levels in phase voltage and ‘2*n*−1’ levels in line, ‘4 + (*n*−3)’ switches are required per phase. Here, four indicate number of switches in H-bridge and ‘*n*−3’ indicate additional unidirectional switches required.

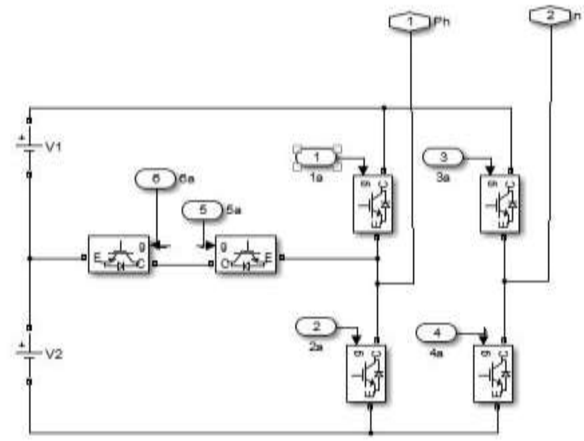

Fig. 6. Fig. inverter topology of leg A of phase A

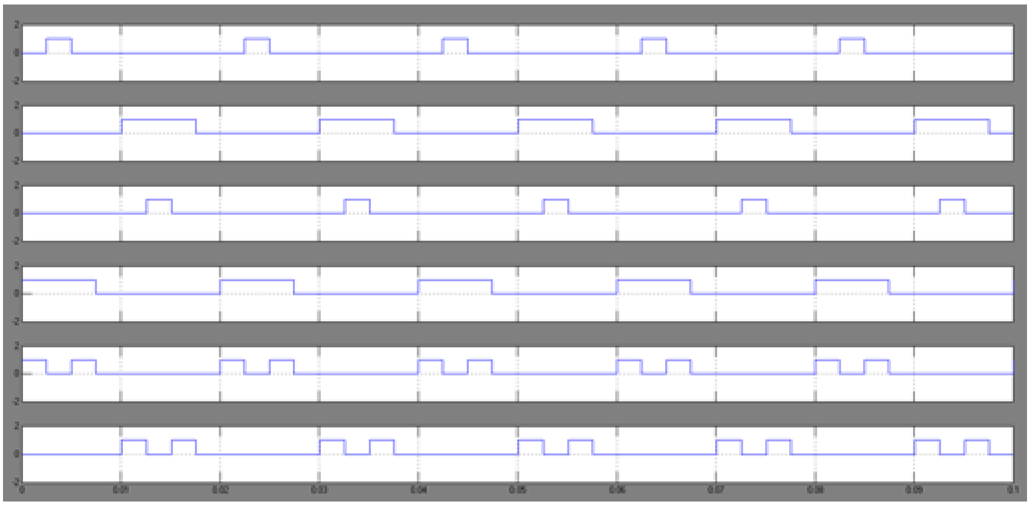

Fig.7. Fig. PWM pulses for switches

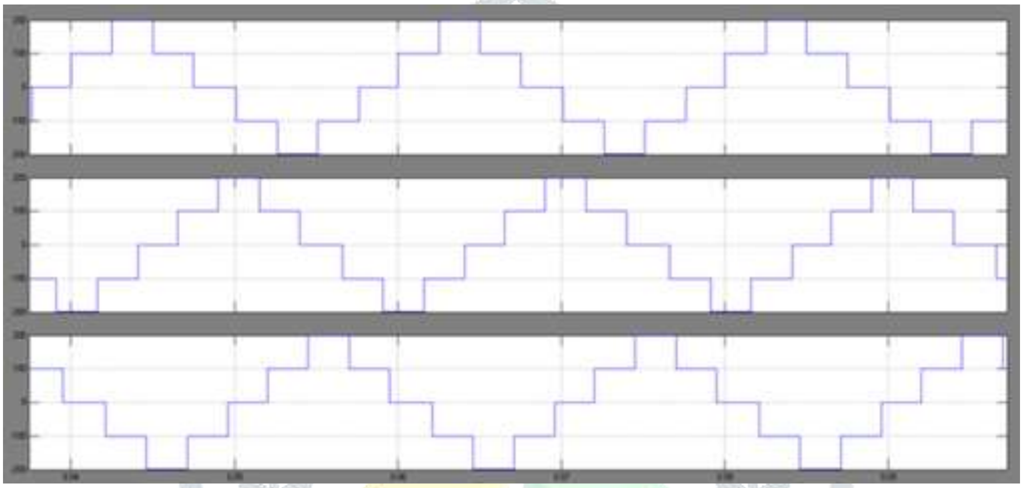

Fig.8 output voltage of the inverter

VI. CONCLUSION

In this paper, the poor harmonic performance of the conventional multi-reference modulation method for T-type MLI topology is analyzed. To address this problem, a modified multi-reference dual-carrier modulation is nominated. The performance of the modulation scheme is identical to LSPWM-IPD technique which is the best PWM technique with the lowest THD value available. Further, to implement the proposed PWM scheme, an alternate carrier and modulation signals arrangement is also proposed which can be easily realizable on digital platforms. The performance of the proposed modulation schemes is evaluated with simulation and experimental studies on a five-level T-type MLI Topology. The empirical studies are in good agreement with simulation studies and also verify the superior performance of the proposed schemes over conventional modulation schemes.

A generalization of the modified, reduced carrier modulation to implement any number of levels for a T-type is presented with the help of a flowchart. Value available. Further, to implement the proposed PWM scheme, an alternate carrier and modulation signals arrangement is also proposed which can be easily realizable on digital platforms. The performance of the proposed modulation schemes is evaluated with simulation and experimental studies on a five-level T-type MLI Topology. The empirical studies are in good agreement with simulation studies and also verify the superior performance of the proposed schemes over conventional modulation schemes. A generalization of the modified, reduced carrier modulation to implement any number of levels for a T-type is presented with the help of a flowchart.

VII. References

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