International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJEMR Transactions, online available on 4th Sept 2019. Link
:http://www.ijiemr.org/downloads.php?vol=Volume-08&issue=ISSUE-09

Title **PHASESHIFTED CARRIER BASED HARMONIZED SINUSOIDALPWM TECHNIQUESFOR DROPPED H-BRIDGE MULTI LEVEL INVERTERS**

Volume 08, Issue 09, Pages: 528–545.

Paper Authors

SK AFRIN, SK NASEEMA, SD REEMA FARHEEN

Anu Bose Institute of Technology K.S.P Road, New paloncha, Bhadradri Kothagudem, Telangana, India

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

PHASESHIFTED CARRIER BASED HARMONIZED SINUSOIDALPWM TECHNIQUESFOR DROPPED H-BRIDGE MULTI LEVEL INVERTERS

SK AFRIN[1], SK NASEEMA[2], SD REEMA FARHEEN[3]
[1,2,3]UG Students,Dept. of Electrical and Electronics Engineering Anu Bose Institute of Technology
KSPRoad, Newpaloncha, BhadradriKothagudem, Telangana, India.
afrinshaik199902@gmail.com[1], naseema4899@gmail.com[2], princessonu46@gmail.com[3]

Abstract:-This paper assessments synchronization approach fell H-Bridge amazed inverter (CHBMLI) topologieswith conveyor based sinusoidal stage moved heartbeat width balance (PSPWM) methodology. In PSPWM framework an alternate transporter isused for eachH-Bridge. The transporters aregenerally stage moved fromeachotherby π/x rad (x=No. of HBridges) forunipolarPWM. Withthe conveyor repeat being an entire number (odd/even) various ofthe fundamental repeat, itis seen thatthe spots ofzero crossing points of the transporters concerning thezero convergences of voltage references accept a noteworthy activity for keeping up quarter wave symmetry among amazed inverter (MLI) post voltagewaveforms. Thispaper demonstratively showsthe conditions for halfwave symmetry and quarterwave symmetry and likely checks thoseconditionsforPSPWM framework with a fivelevelCHBMLI lab model.

Index Terms:-CascadedH-Bridge MultilevelInverter, Phaseshiftedcarrier based PWM, SynchronousPWM, HalfWaveSymmetry, QuarterWaveSymmetry.

I. INTRODUCTION

Withthe growing solicitation of medium voltage and high powerdrives, the useof stunned invertersis well ordered winding up progressively critical. This is a direct result of reduced voltage weight on semiconductor devices, diminished music ininverteryieldvoltage and lesser electromagnetic impedances. For medium voltage and high power applications, the trading repeat and device evaluations are confined [1]-[3]. Extending the powerrating by restricting the trading repeat, while up 'til now keeping up reasonablepowerquality is a huge need and a relentless test [2]-[3]. Therefore, the use of amazed inverters fittingly passes on thestress. Among the unmistakable amazed invertertopologies, the fell H-Bridge (CHB) topology is a favored choice for medium voltagedrives for its disposition and thisis furthermore the target converter for the proposed PWM methodology inthis paper. In highpower and mediumvoltage applications, the powerconverters work at low trading repeat. Thisis especially portrayed inthe composition as low heartbeat extent action ofthe converters. The applications contain balance drives (both VSIandCSIenergizeddrives), cross section applications (as bi-directional converters, dynamic power channels, etc. Asthe beat extent is less in these power converters, lower demand music including sub-sounds are introduced in line streams achieving

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

higher full scale symphonious mutilation (THD). Hereafter, synchronization among PWM voltages is fundamental. Close by synchronization, the PWM voltage should keep up halfwave, quarterwave and three phase symmetries [4]-[5]. Reference [6] exhibits the upsides of keeping up the above waveformsymmetries.The synchronization ensures the PWMvoltageisfree from the sub-music. Threephase symmetry among the PWMvoltages ensures the major and the music arebalanced and moreover free from dc offset. Also, three phase symmetry similarly ensures that, the triplen sounds are in stage and appear as zero gathering voltage with the advantage of not adding to the swell current. Half wave symmetry ensures the PWM voltages are free from even solicitation music. Notwithstanding the way that quarter wave symmetry does not get rid of any sounds, it ensures that the present fundamental and music have simply sine part and discards the probability of stage botch between the reference and the basic yield voltage. Reference [7] proposes a perfect PWM scheme for two level inverters to reduce current music with detached figurings of trading plan. This improved PWM framework can moreover be extended to stunned inverters. Reference [8] exhibits the utilization of synchronized perfect PWM methodology for a fell nine level inverter, where the typical device trading repeat is confined to assessed head repeat. Reference [9] considers the presentations of five level and seven level NPC inverters with synchronous perfect PWM technique. In any case, the synchronized perfect PWM technique is a separated tally based framework. The trading focuses are pre-decided tolerating enduring state condition and this requires amassing of gigantic data for better exactness. Reference [10] proposes a bearing after control for three level NPC with synchronous perfect PWM methodology. Reference proposes the model insightful heartbeat model control for a five level NPC inverter with streamlined PWM framework. Specific consonant transfer and explicit symphonious help PWM strategies are various choices. Reference exhibits the use of SHEPWM methodology for course amazed inverters, however shows the use of SHMPWM technique. Regardless, they are furthermore detached estimation based PWM methodology and require inquiry tables for execution, along these lines the more microcontroller memory space. References show the utilization of online consonant compensation intend to improve the existingSHEPWM technique for high power converters. These references generally revolve around cross section related high power converters (for instance current source rectifiers). All the above stunned inverter PWM frameworks (SOPWM, SHEPWM and SHMPWM Techniques, leaving on the web consonant compensation plot) rely upon disengaged estimations. The figuring multifaceted design increases with augmentation in number of voltage levels or addition in the amount of reward focuses at lower equalization records. Regardless, the carrier based PWM techniques are self-sufficient of motor parameters, free of progress and does not require detached calculation or investigate tables to make ending focuses. In this manner, conveyor based PWM technique is fitting to stunned inverters in spite of the way that the symphonious substance of the inverter yield post voltage are not improved. Two transporter based PWM frameworks are available recorded as a hard copy for MLIs. They are:- (I) Level moved PWM methodology (LSPWM technique) (ii) Phase moved PWM procedure (PSPWM framework). Nevertheless, the genuine test for the transporter based PWM systems for MLIs is to position the zero crossing points of bearers' with concession tothe zero convergences of voltage references so different symmetries among post voltage waveforms can be kept up. For two-level inverters, synchronization with different symmetries is reachable if the zero crossing points of the transporter matches with the zero convergences of the voltage references and the extent p' (p=fc/fs where fc= bearer recurrence and fs=voltage reference recurrence) is kept up to be an odd number (various of 3). The transporter synchronization with the voltage references is satisfactory for the Level Shifted PWM (LSPWM) strategy for CHBMLIs, as only a solitary synchronous conveyor is sufficient to complete various voltage levels. Thusly, the post voltage keeps up all the basic properties of an ideal synchronous PWM technique. Regardless, the power course and typical device trading frequencies of different H-Bridges are uncommon. Regardless, this circumstance is absolutely phenomenal for the PSPWM framework, as various stage moved synchronous transporters are used for different H-Bridges. Along these lines, it is hard to arrange the zero crossing points of each transporter with the voltage reference zero convergences. In this way, the spots of the zero convergences of voltage references concerning the zero crossing points of transporters expect a huge activity for keeping up different central properties of an ideal synchronous PWM, as communicated in the past segment. This paper basically deals with the insightful assessments for keeping up half wave symmetry and quarter wave symmetry among CHBMLI shaft voltage waveform with synchronous sinusoidal PSPWM methodology. The transporters used for the assessment in this paper are created from the brief voltage references, as in [17]-[19] and reliably keep up an entire number extent p.

II.CONDITIONS OFPHASE SHIFTED SYNCHRONOUSPWM FORCHBMLI

The unipolar PWM system is utilized for producing door beats for every H-Bridge. TheH-Bridge shaft voltage fluctuates between 0to +Vdc when the indication of the voltagereference is sure and changes between 0 to - Vdc whenthe indication of the voltagereferenceisnegative (where Vdc isthe information DC interface voltageof the H-Bridge). For actualizing unipolar PWM in a H-Bridge1 (Fig.1.(a)), apositive voltage reference R1 is utilized to create entryway beats forswitches S11 and S12 of leg1 and a negativevoltage reference R2 is utilized to produce door beats forswitches S13 and S14 of leg2. A typical bearer CHB1 is utilized for both the legs so as to produce door beats. The resultant yield post voltage VHB1 is the arithmetical summationof individual legvoltages for example VHB1=VHBL1-VHBL2.

A. Verification of Synchronization

The synchronization between voltagereference and essential segment ofinverter yield shaft voltage canbe kept up ifthe synchronous bearer recurrence is (n being any whole number) times the voltagereference recurrence. By keeping up the abovecondition the convergence focuses between the transporter and the voltagereference (for example in a key cycle of the voltage reference) rehash after2πrad (for example the following sequential principal cycle ofthevoltagereference), thus synchronizationis kept up.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

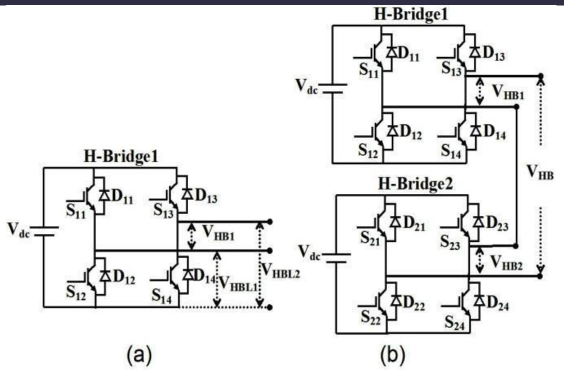

Fig.1(a) SingleH-Bridge ; (b)Double CascadedHBridges.

B.Verification of ThreePhase Symmetry &HalfWaveSymmetry

Withsynchronous bearers having 3ntimes the essential recurrence (n beingany number) being utilized forthePSPWM strategy, three stage symmetry is constantly kept up amongindividual H-Bridge yield shaft voltagewaveforms. Additionally, from Fig.2.(a)it tends to be seen that, for an odd number proportion betweenthe bearer and major recurrence, the locale fromπrad to 2πrad is proportionate toa perfect representation of the area from0radtoπrad as for xaxis(θ). Consequently, the crossing point guides C1 toward C6 are the perfect representations of focuses from C7 to C12 separately. Truth be told, for an odd whole number proportion, singular shaft voltages of boththelegs (VHBL1 and VHBL2) of one H-connect keep up halfwave symmetry and henceforth their distinction additionally keeps up half wave symmetry. In the event that the proportion is even, at that point, singular shaft voltages of both the legs (VHBL1 and VHBL2) don't keep up half wave symmetry. In any case, the waveform of VHBL1 from 0rad to πrad is a definite imitation of VHBL2 from πrad to 2πrad and the other way around. Thus, their distinction (for example VHB1= VHBL1-VHBL2) keeps up half wave symmetry. Henceforth, for a H-connect, the half wave symmetry is fulfilled for any transporter having its recurrence equivalent to number (odd/even) various of the principal recurrence. Subsequently, it very well may be presumed that the inverter shaft voltage waveform keeps up three stage and half wave symmetry for bearers having 3n times the principal recurrence (n being any odd/much number). It is along these lines just important to decide the conditions for quarter wave symmetry in the inverter yield shaft voltage waveform.

.

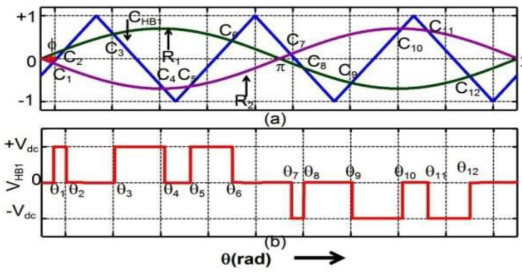

Fig. 2.(a) CarrierC_{HB1} lagging the normalized voltagereferences R_1&R_2 by Φrad (f_c/f_s=3) ; (b) pole voltage V_{HB1}.

C.Determination of conditionsfor Quarter WaveSymmetry 1)SingleHBridge

The quarterwave symmetry among shaft voltagewaveform of a H-Bridge (Fig.1.(a)) can be kept up, ifthepositivezero convergence of the voltagereference relates with the positivezero crossing point of the conveyor. The institutionalized fundamental voltagereferences are sinewaves with their adequacy not actually or comparable toone. The bearers are triangularwaves with the size of their positive&negative apex comparable toone. Positive zero convergence suggests, the prompt estimations ofthese irregular waveforms have completed their negative half cycles and become zero going before entering the positive half cycle.The transporter can be of two sorts. They are: - (I) In stage transporter (positive zero crossing point of positive

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

voltage reference matches with the positive zero convergence of the conveyor) (ii) Out of stage carrier (positive zero crossing point of the positive voltage reference relates with the negative zero convergence of the transporter). For transporter repeat being an odd diverse of the basic repeat, particular shaft voltages of both the legs (VHBL1 and VHBL2) keep up quarter wave symmetry guaranteeing quarter wave symmetry of the extension yield voltage VHB1. For bearer recurrence being an even numerous of the principal recurrence, singular shaft voltages of both the legs (VHBL1 and VHBL2) don't keep up quarter wave symmetry. Be that as it may, their distinction VHB1= VHBL1-VHBL2 keeps up quarter wave symmetry. On the off chance that the bearer is stage deferred by π/2rad (where 2πrad is one transporter period), at that point the turn around marvel occurs. Presently, for transporter recurrence being an even numerous of the essential recurrence, singular post voltages of both the legs (VHBL1 and VHBL2) keep up quarter wave symmetry. While, for bearer recurrence being anodd various ofthe basic recurrence, singular shaft voltages of both the legs (VHBL1 and VHBL2) don't keep up quarter wave symmetry. Be that as it may, their distinction VHB1= VHBL1-VHBL2 keeps up quarterwave symmetry. This can likewise be determined numerically as appeared inthe accompanying talk. As a particular casethe bearer recurrence is taken tobe multiple timesthe crucial recurrence. FromFig.2, for keeping up quarterwave symmetry ofthe post voltagewaveform VHB1, the imperative tobe fulfilled among voltage reference and bearer crossing point directs C1 toward C6 is given by (1).

$$\theta_{7-l} = \pi - \theta_l \quad \text{for } l = 1, 2 \text{ and } 3 \qquad (1)$$

For l=1, the estimations of θ1 and θ6, at focuses C1 and C6 can be discovered by likening the conditions of voltage reference's and the carrier's. A little advance is appeared underneath to decide the conditions of voltage references and transporters at focuses C1 and C6 with the assistance of the conditions (2), (3), (4) and (5). Fig.3 demonstrates the broadened perspective on voltage references R1 and R2 alongside transporter CHB1. The point C1 (whose follow is θ1 along x-pivot (θ)) is the crossing point between voltage reference R2 and line AB which is one piece of the transporter CHB1. The condition of the voltage reference at C1 can be composed as

$$z_1 = -m\sin\theta_1 \qquad (2)$$

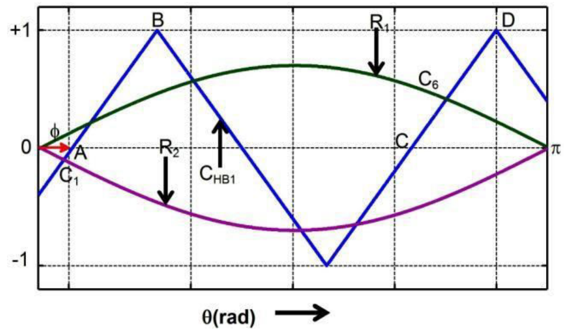

Fig. 3.Carrier C_{HB1} lagging the normalized voltage references R_1 and R_2 by Φrad (f_c/f_s=3).

The co-ordinates of the points A and B are (Φ, 0) and (Φ+π/6, 1) respectively. Hence, the equation of the line AB at point C_1 can be written as (3).

$$z_1 = \left(\frac{6}{\pi}\right)(\theta_1 - \phi) \qquad (3)$$

Similarly, the point C_6 is the intersection point between R_1 and line CD (which is a portion of carrier C_{HB1}).

The equation of the voltage reference at C_6 can be written as (4).

$$z_6 = m\sin\theta_6 \qquad (4)$$

The co-ordinates of the points C and D are (2π/3+Φ, 0) and (Φ+5π/6, 1) respectively.

Hence, the equation of the line CD at point C_6 can be written as (5).

$$z_6 = \left(\frac{6}{\pi}\right)\left(\theta_6 - \frac{2\pi}{3} - \phi\right) \quad (5)$$

Where z_1& z_6 = y-axis values at points C_1 and C_6 respectively m=modulation index of voltage references R_1 and R_2

From equations (2), (3), (4) and (5), the intersection angles θ_1 and θ_6 at points C_1 and C_6 can be found out by equating the equations of voltage references and carriers and can be written as (6) and (7) respectively.

$$-m\sin\theta_1 = \left(\frac{6}{\pi}\right)(\theta_1 - \phi) \quad (6)$$

$$m\sin\theta_6 = \left(\frac{6}{\pi}\right)\left(\theta_6 - \frac{2\pi}{3} - \phi\right) \quad (7)$$

Equation (7) can be modified as (8) by putting the constraint of quarter wave symmetry (2).

$$m\sin\theta_1 = \left(\frac{6}{\pi}\right)\left(\frac{\pi}{3} - \theta_1 - \phi\right) \quad (8)$$

By adding equations (6) and (8), the value of □ can be found as (9).

$$\phi = \pi/6 \, rad \quad (9)$$

Equation (9) shows the condition for quarter wave symmetry among pole voltage waveforms VHB1, when p=3.For carriers having frequency p=3n (where n=1, 3, 5, 7,9,……,etc.) times the fundamental frequency and with their zero crossings lagging the fundamental voltage reference zero crossings by Φrad, the condition for quarter wave symmetry among pole voltage waveform VHB1 can be found by using (10)-(14). Here, for quarter wave symmetry, the constraint isgiven by (10).

$$\theta_{6n+1-l} = \pi - \theta_l \quad \text{for } l = 1, 2, ...3n \quad (10)$$

For l=1

$$-m\sin\theta_1 = \left(\frac{6n}{\pi}\right)(\theta_1 - \phi) \quad (11)$$

$$m\sin\theta_{6n} = \left(\frac{6n}{\pi}\right)\left\{\theta_{6n} - \phi - \frac{(3n-1)}{3n}\pi\right\} \quad (12)$$

By putting the constraint of quarter wave symmetry $\theta_{6n} = \pi - \theta_1$ in (12), one gets

$$m\sin\theta_1 = \left(\frac{6n}{\pi}\right)\left(\frac{\pi}{3n} - \theta_1 - \phi\right) \quad (13)$$

By adding (11) and (13), the value of can be found as (14).

$$\phi = \left(\frac{1}{3n}\right)\left(\frac{\pi}{2}\right) rad \quad (14)$$

Thus, by speaking to Φ regarding bearer period, it tends to be presumed that, for keeping up quarter wave symmetry among post voltage waveform VHB1, the zero intersection of the transporter should slack the zero intersection of the voltage reference by π/2 rad.

1. The zero intersections of the voltage references ought to concur with the zero intersections of the bearer.
2. The zero intersections of the bearer ought to be set at ±π/2 rad with deference tothe zero intersections of the voltage references (where 2π rad signifies one transporter period).

In the event that we have just two H-Bridges per stage, at that point their individual bearers ought to be stage moved from one another by π/2rad. One transporter can fulfill condition I and the other bearer can fulfill condition II as portrayed previously. The yield voltage of both the H-Bridges will keep up quarter wave symmetry and henceforth their total will likewise keep up quarter wave symmetry. Yet, as the quantity of fell H-Bridges builds (more than two) it is beyond the realm of imagination to expect to put all the zero intersections of transporters at 0rad or ±π/2rad regarding the zero intersections of voltage references, as the stage distinction between (π/x rad for x≥2 number of fell H-spans) zero intersections of the bearers diminishes. For two fell H- Scaffolds, the following area manages the conditions for keeping up quarter wave symmetry among resultant post voltage VHB, where the zero intersections of the bearers are put other than 0rad or ±π/2rad regarding the voltage reference zero intersections. 2) Two Cascaded H-Bridges For two fell H-Bridges (Fig.1.(b)), it is additionally conceivable to keep up quarter wave symmetry among the resultant shaft voltage waveform VHB, regardless of individual scaffold voltage waveforms VHB1 and VHB2 not keeping up quarter wave symmetry. Two methodologies are conceivable and pointed beneath. Both the methodologies are broke down in the coming segments.

1.Zero intersections of transporters CHB1 and CHB2 are put on the two sides of the zero intersection of bearer Cref1 (where Cref1 is an invented bearer whose zero intersections are in stage with the zero intersections of the voltage references R1 and R2).

2.Zero intersections of bearers CHB1 and CHB2 are set on the two sides of the zero intersection of transporter Cref2 (where Cref2 is an imaginary bearer whose one positive or negative pinnacle shows up in a similar moment as that of the zero intersections of the voltage references R1 and R2).In different words, it very well may be expressed that Cref1 fulfills condition I and Cref2 fulfills condition II. The transporters CHB1 and CHB2 are utilized for producing entryway beats of H-Bridge1 and H-Bbridge2 individually in a twofold fell H-Bridge (Fig.1.(b)). The voltage reference R1 is utilized for creating the door beats of S11, S12, S13 and S14. The entryway beats of S13, S14, S23 and S24 are produced by voltage reference R2. Fig.4 and Fig.5 demonstrate the voltage references, R1 and R2 alongside transporters CHB1 and CHB2 with deference tothe imaginary bearers Cref1 and Cref2 separately.

A) Approach I

Fig.4 demonstrates the case, where the zero intersection of bearer CHB1 drives the zero intersection of imaginary transporter Cref1 by Φ1rad, while the zero intersection of transporter CHB2 slacks the zero intersection of Cref1 by Φ2rad for p=3. Fig.4.(b) demonstrates that the resultant shaft voltage VHB, does not keep up quarter wave evenness. So as to demonstrate the crossing point focuses and convergence edges, just the half cycle of every waveform is appeared in Fig.4. For keeping up quarter wave balance of the subsequent shaft voltage VHB, the condition to be fulfilled among voltage reference and bearer convergence guides C1 toward C12 is given by (15).

$$\theta_{13-l} = \pi - \theta_l \quad \text{for } l=1, 2, 3, 4, 5 \text{ and } 6 \qquad (15)$$

For l=1, thevalues of θ_1 and θ_{12}, atpoints C_1&C_{12}canbe found outbyequatingtheequationsofvoltagereferencesandcarriers and canbewrittenas(16)and(17) respectively.

$$-m\sin\theta_1 = \left(\frac{6}{\pi}\right)(\theta_1 - \phi_2) \qquad (16)$$

$$-m\sin\theta_{12} = -\left(\frac{6}{\pi}\right)(\theta_{12} - \pi + \phi_1) \qquad (17)$$

Equation (17) canbemodifiedas(18) by puttingthe condition of quarterwave symmetry (15).

$$m\sin\theta_1 = \left(\frac{6}{\pi}\right)(\phi_1 - \theta_1) \qquad (18)$$

Byadding (16) and (18), thecondition for quarterwave symmetry canbe found outas (19).

$$\phi_1 = \phi_2 \qquad (19)$$

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

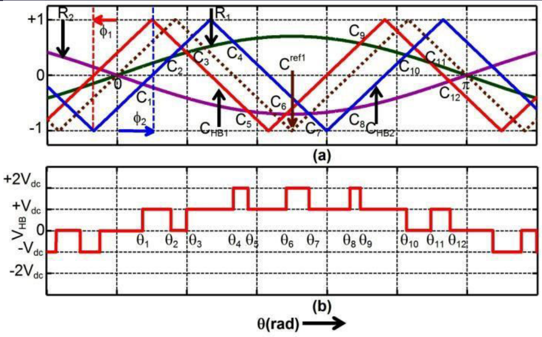

Fig. 4.(a)References R_1 and R_2andCarriers C_{HB1} and C_{HB2} when C^{ref1}isinphase with voltagereferences (p=3); (b)V_{HB}.

From (19) itcanbeobservedthatthequarterwave symmetry amongresultant pole voltagewaveform V_{HB}canbe maintained if $\Phi_1 = \Phi_2$, i.e. thezero crossings ofcarriers C_{HB1} and C_{HB2} are placedequidistantly from thezero crossings ofcarrier C^{ref1}. Ina similar waythe conditions for quarterwave symmetry attheotherintersectionpointscanalsobederived and eachpair of intersection points will result in the condition of (19). Equation (19) showsthe condition for quarterwave symmetry amongpolevoltagewaveform V_{HB}, whenp=3. Forcarriers having frequencyp=3n(where n=1, 2, 3, 4, 5, 6, 7, 8, 9, 10,……,etc.) times the fundamentalfrequency and withtheirzerocrossings lagging and leadingthe zero crossingof C^{ref1} by $\Phi_1$rad and $\Phi_2$radrespectively, thecondition for quarterwave symmetry amongresultant pole voltagewaveform V_{HB}canbefoundby using theabove approaches.

b) Approach II

In thesecondapproach(Fig.5), thezerocrossingof carrier C_{HB1} leads thezerocrossingof carrier C^{ref2} by $\Phi_1$rad, whereas thezero crossing of carrier C_{HB2} lags thezero crossing ofcarrier C^{ref2} by $\Phi_2$rad forp=3. Fig.5.(b) showsthat the resultantpole voltage V_{HB}doesnot maintain quarterwave symmetry. For maintaining quarterwave symmetry amongresultant pole voltagewaveform V_{HB}, the condition tobesatisfiedamongvoltagereference and carrier intersectionpoints C_1 to C_{12}isgivenby (20).

$$\theta_{13-l} = \pi - \theta_l \quad \text{for } l = 1, 2, 3, 4, 5 \text{ and } 6 \qquad (20)$$

Forl=1, thevalues ofθ_1&θ_{12}, atpoints C_1 and C_{12}canbe found outbyequatingtheequationsofvoltagereferences and arriers and canbewrittenas (21) and (22) respectively.

$$-m\sin\theta_1 = \left(\frac{6}{\pi}\right)\left(\theta_1 - \frac{\pi}{6} + \phi_1\right) \qquad (21)$$

$$m\sin\theta_{12} = \left(\frac{6}{\pi}\right)\left(\theta_{12} - \frac{5\pi}{6} - \phi_2\right) \qquad (22)$$

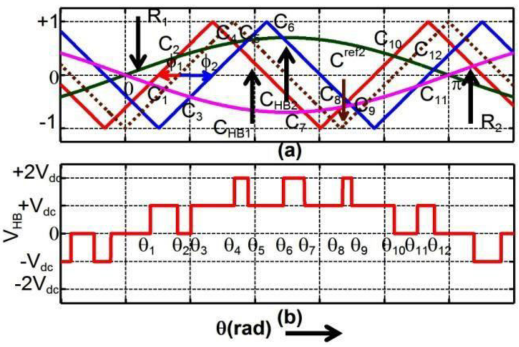

Fig. 5.(a) References R_1 and R_2 and Carriers C_{HB1} and C_{HB2} when C^{ref2} is π/2 radlaggingwithrespect to voltagereferences(p=3); (b)V_{HB}.

Byputtingthecondition of quarterwavesymmetry(20)in(22) canbesimplifiedas (23).

$$m\sin\theta_1 = \left(\frac{6}{\pi}\right)\left(\frac{\pi}{6} - \theta_1 - \phi_2\right) \qquad (23)$$

Byadding (21)&(23), thecondition for quarterwave symmetry canbe found outas (24).

$$\phi_1 = \phi_2 \qquad (24)$$

From (24) itcan be observed that, herealso the quarterwave symmetry amongresultant pole voltagewaveform V_{HB}canbemaintainedif $\Phi_1 = \Phi_2$, i.e. thezero crossings ofcarriers C_{HB1} and C_{HB2}areequidistant from thezero crossing

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

ofcarrier C^{ref2}. The conditionofquarterwave symmetry canalsobeshown as$\Phi_1=\Phi_2$, ifthezerocrossingof carrier C^{ref2} lead π/2rad fromthezero crossing ofthevoltagereferences. Same conditionforquarterwave symmetry can be derivedfor carriers havingfrequencyp=3n (where n=1, 2, 3, 4, 5, 6, 7, 8, 9, 10,……,etc.) timesthefundamental frequency.

c) Conditionsforquarterwave symmetry with x(≥2) numbersofcascaded H-BridgesTABLE-I

Three Cascaded H-Bridges

Position of C_{HB1}	Position of C_{HB2}	Position of C_{HB3}
$\mp\pi/3$rad	0rad	$\pm\pi/3$rad
$\mp\pi/6$rad	$\pm\pi/6$rad	$\pm\pi/2$rad
$\mp\pi/6$rad	$\mp\pi/2$rad	$\mp 5\pi/6$rad
0rad	$\mp\pi/3$rad	$\mp 2\pi/3$rad

Zero crossing of voltage reference is placed at 0rad

From the past exchanges on quarter wave balance, it very well may be broadened that there can be numerous methodologies of keeping up quarter wave evenness among the resultant post voltage waveform. for example in the event that there are two Hbridges, at that point one methodology can be to put one transporter concurring with Cref1 and the other bearer harmonizing with Cref2. Another methodology can be to put two bearers with the end goal that one transporter drives Cref1 (or Cref2) by π/4rad and the other transporter slacks Cref1 (or Cref2) by π/4rad. On the off chance that there are three fell H-Bridges, at that point the potential methodologies are given as a table in TABLE-I. Subsequently, it is essential to decide the general way of thinking of putting the transporters as for the voltage reference to guarantee quarter wave evenness for a (2x+1) level fell H-Bridge staggered inverter (x number of fell H-Bridges). The way of thinking is diagnostically clarified in this area. For this examination, position of a bearer is characterized by the situation of the zero intersection of the transporter.

<u>Case</u>:-I (Withone carrier being at0^{th} position (0^{th} carrier), **k**numbersofcarriersarepresentonthe left handside(**between pointsAandB**) and(**x-k-1**)numbersofcarriersare present onthe right handside(**betweenpoints D&H**) ofthe0^{th} carrier). Itistobe noted that thezero crossing of voltagereference R coincideswiththezero crossing ofthecarrierplaced at 0^{th}position.

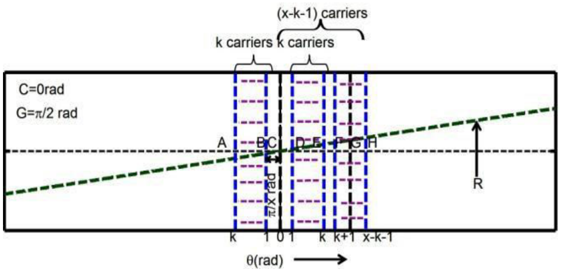

Fig. 6.Positivezero intersection (pointC) of standardized voltagereference R harmonizes with the positivezero intersection (pointC) of 0th transporter.

Fig.6 demonstrates the case:- I, wherek quantities of bearers are available onthelefthandside of 0th transporter and (x-k-1) quantities of transporters are available on the correct handsideof 0th bearer. Thezero intersections every bearer isolated from one another by π/xrad. The positive zero intersection ofthe standardized voltage reference R concurs with the positive zero intersection of 0th bearer. Itcan likewise be seen fromFig.6 that, equivalentnumbers of bearers are available around point C between focuses A-B&D-E. Henceforth, theresultant yield shaft voltagewaveformofthe H-Bridges utilizing these transporters keeps up quarterwave

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

symmetry. Additionally, the post voltageyieldofthe H-Bridge utilizing 0th transporter keeps up quarterwave symmetry. Subsequently, keeping up quarterwave symmetry amongtheresultant post voltagewaveform of x quantities of fell HBridges it ought to be demonstrated that the positivezero intersections of transporters bearers between focusesF-H)are available equidistantlyfrom π/2rad (point G).The removes between focuses G-FandH-G are determined as (25)and(26).

$$FG=\frac{\pi}{2}-(k+1)*\left(\frac{\pi}{x}\right)=\left(\frac{x-2k-2}{2}\right)*\left(\frac{\pi}{x}\right) \quad (25)$$

$$GH=(x-k-1)*\left(\frac{\pi}{x}\right)-\frac{\pi}{2}=\left(\frac{x-2k-2}{2}\right)*\left(\frac{\pi}{x}\right) \quad (26)$$

Equations(25)&(26) shows thatthepositivezero crossings of $(k+1)^{th}$ and $(x\text{-}k\text{-}1)^{th}$carriersare placed equidistantlyfrom π/2rad.

The above explanation can be extended to even/odd numbers of cascaded H-bridges. For an even number of cascaded H-Bridges one carrier is present at π/2rad and equal numbers of carriers are present on both sides of π/2rad. For an odd number of cascaded H-Bridges no carrier is present at π/2rad and equal numbers of carriers are present on both sides of π/2rad.

<u>Case</u>:-II (**k** numbers of carriers are present on the left hand side **(between points A and B)** and **(x-k)** numbers of carriers are present on the right hand side (**between points D and H)** of the point C (the mid-point of points B and D) and the positive zero crossing of voltage reference R coincides with point C). There is no 0^{th} carrier in this case.

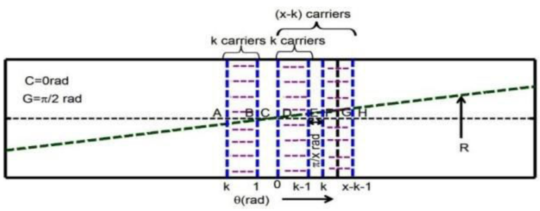

Fig. 7.Positivezero intersection (pointC) of standardized shaft voltagereference R is set in the middle of the positivezero intersections (focuses BandDoftwo adjoining bearer sets). Fig.7 demonstrates the case:II, wherek quantities of transporters areavailable on the lefthandside of pointC and (x-k) quantities of bearers are available on the correct handside of pointC. The zero intersections of every bearer are isolated from one another byπ/xrad. The positive zero intersection of the standardized voltage referenceR corresponds with the point C (mid-purpose ofthetwo contiguous bearers). It likewise canbe seen fromFig.7 that, equivalent numbersof transporters are available around pointC between focuses A-B and D-E. Consequently, theresultant yield post voltagewaveform of the H-Bridges utilizing these transporters keeps up quarterwave symmetry. For keeping up quarterwave symmetry among the resultant post voltagewaveform of x quantities of fell H-Bridges it ought to be demonstrated thatthepositivezero crossings of k^{th} and $(x\text{-}k)^{th}$ carriers(among n-2k carriersbetweenpointsF&H) are present equidistantly fromπ/2rad (pointG).

Thedistances between pointsG-F and H-G are calculatedas (27) and (28).

$$FG=\frac{\pi}{2}-\left\{k*\left(\frac{\pi}{x}\right)+\frac{\pi}{2x}\right\}=\left(\frac{x-2k-1}{2}\right)*\left(\frac{\pi}{x}\right) \quad (27)$$

$$GH=\left\{(x-k-1)*\left(\frac{\pi}{x}\right)+\frac{\pi}{2x}\right\}-\frac{\pi}{2}=\left(\frac{x-2k-1}{2}\right)*\left(\frac{\pi}{x}\right) \quad (28)$$

Equations (27)&(28) show thatthepositivezero crossings ofk^{th} and $(x\text{-}k)^{th}$carriersare placed equidistantlyfromπ/2rad. Theabove clarification canbe stretched out toeven/odd quantities of fell H-spans. For a considerably numberof fell H-Bridges no transporter is available atπ/2rad and equivalent quantities of bearers are available

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

on the two sidesofπ/2rad. For an odd number of fell H-Bridges one transporter is available atπ/2rad &equivalent quantities of bearers are available on the two sidesofπ/2rad.

d)GeneralizedConditionformaintainingQuarterWaveSymmetry

TABLE-II

x Cascaded H-Bridge Multilevel Inverters. (There are x phase shifted carriers with π/x phase difference between any two adjacent carriers)

CONDITION FOR QUARTER WAVE SYMMETRY $f_c/f_s=3n$ (where n=1,2,3,4,… etc.)	
1	Zero crossing of voltage reference coincides with zero crossing of any carrier
2	Zero crossing of voltage reference is placed at the mid-point between positive (or negative) zero crossings of any two adjacent carriers

TABLE-II abridges theconditions to keep up quarterwave symmetry among resultant post voltagewaveform for x (x≥2) quantities of fell H-Bridge inverter. Itis to be noticed that, itis required to fulfill any onecondition referenced in Table II so as to keep up quarterwave symmetry. Itis seen that in the event that any of these conditions is kept up, at that point forgetting about the in-stage and π/2rad-stage bearers (on the off chance that theyexist), equivalent numberof transporters willbe set on the two sides of Cref1 (as appeared inFig. 4) or Cref2 (as appeared inFig.5) orboth.e)Power appropriation betweeneverycell

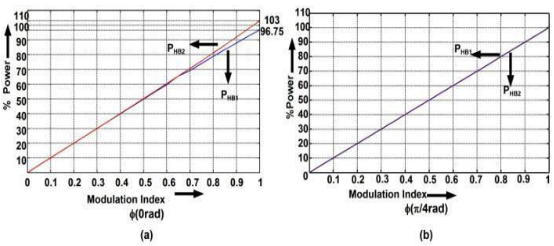

Fig.8Power appropriation between every H-Bridge ofafivelevelCHBMLI (a) Positivezero intersection of CHB1 corresponds withthezero intersections of R1 and R2 and (b)Zero intersections of R1 and R2 are set at±π/4radwith deference tothezero intersections of CHB1&CHB2 forp=3.

ForPSPWM system withahigh exchanging recurrence, every H-Bridgehandles equivalent power. Yet, whenthe proportion p turns out to be low, inconsistent power dissemination happens betweenthefell H-Bridges. The reasonis, samecurrent goes through every module. In any case, their immediate yield voltagewaveforms are unique. Subsequently, the immediate power incorporated overa total principal cycle mayresult is various qualities. Fig.8 demonstrates that, whenthe zero intersections of the voltagereferences match withthezero intersection of one of the bearers, state of inconsistent conveyance of intensity betweenthe H-Bridges happen. However, when the zero intersections of the voltagereferences are put equidistantly between the zero intersections of thetwo bearers, at that point every H-Bridge offers equivalent power. Itistobe noticed this is only a particular model. Inageneral x CHBMLIs inconsistent power conveyance may occurforlesser estimation ofp.

f)Fundamentaldisplacement and harmonicdistortionwithoutmaintaining QWS

In order to study the importance of maintaining QWS, with p=3, the angle Φ (distance between the zero crossing of voltage reference and the positive zero crossing of C_{HB1}) is varied in H-Bridge1 (Fig.1.(b)) from 0 rad to π/6rad (0rad to π/2rad in terms of carrier period). Hence, the positive zero crossing of C_{HB2} varies from π/6rad to π/3rad with respect to the fundamental reference (π/2 rad to π rad in terms of carrier period). Fig.9.(a) shows that, for a single H-bridge (Hbridge1), maximum phase displacement (α_{HB1}) occurs between the voltage reference and the fundamental of pole voltage for Φ=π/4rad (in terms of carrier period). At both the

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

extreme ends, i.e. at Φ=0rad (Condition of QWS) and Φ=π/2rad (Condition of QWS) the phase displacements are zero. Similarly, the Fig.9.(b) shows at Φ=0rad (Condition of QWS), Φ=π/4rad (Condition of QWS) and Φ=π/2rad (Condition of QWS) the phase displacements are zero for the double cascaded H-Bridges. Fig.9 also shows that the phase displacement for a single HB is higher comparing to the double cascaded HBs. If the number of cascaded H-bridges is further increased, then the phase displacement reduces to lesser values and hence, for a very large number of cascaded H-bridge cells, with phase shifted carriers, phase displacement of the resultant pole voltage is negligible even without perfect quarter wave symmetry.

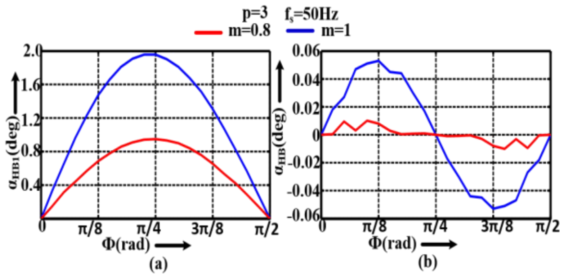

Fig. 9.Fundamentalvoltage displacements of (a) Single H-Bridgeand (b) Doublecascaded H-Bridgesforp=3 ,f_s=50Hzandwith modulationindexes of 0.8 and 1.

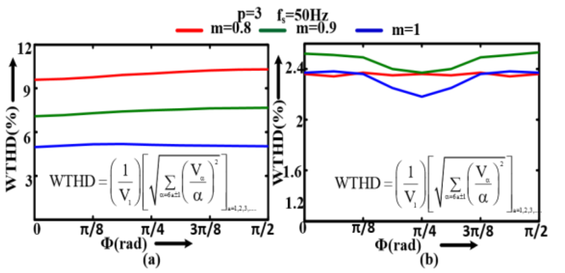

Fig. 10.WTHD (linevoltageV_{RY}) variationsw.r.t thevariationofΦforhighermodulationindexes (0.8 t0 1)for (a)single H-Bridgeand (b) doublecascaded H-Bridges with p=3 , f_s=50Hz. In order to check the variation of the harmonic profile of the line voltage with respect to the variation of Φ (distance between the zero crossing of voltage reference and the positive zero crossing of C_{HB1}), the WTHD plots for line voltage V_{RY}, are plotted in Fig.10 for a three level (single H-bridge) and five level (two cascaded H-bridges) CHBMLI, for three modulation indexes 0.8, 0.9 and 1, with p=3 and f_s=50Hz. For single H-bridge, the positions Φ = 0rad and π/2rad are the conditions for quarter wave symmetry whereas for two cascaded H-bridges, the positions 0rad, π/4rad and π/2rad are the states of keeping up QWS among shaft voltage waveform. Here, it tends to be seen that for a solitary H-connect, WTHD fluctuates nearly in a level profile. For two fell Hbridges, for higher adjustment files, least WTHD happens at Φ=π/4rad (for example the zero intersection of voltage reference is put at the midpoint of the zero intersections of two bearers) which is a legitimate condition for quarter wave symmetry. The improvement is obviously unreasonably little for thought in a handy circumstance. The proposedPSPWM system doesnotgive a superior symphonious voltageprofile contrasted with the strategies proposedin[8][20][21] asthe door heartbeats are created with no consonant minimization method. References[8]|&[21] demonstrate the utilizations ofSOPWM method, wherethe exchanging moments are determined for limiting certain voltage music alongside minimization of current mutilation. Reference [20] computes the exchanging moments by limiting the required voltage sounds alongside the limitation of limiting the throbbing torque. The proposed PSPWM method does not profess to give diminished current or torque swell. Be that as it may, it tends to be expressed that with lower p and decreased number of H-Bridges the proposed PSPWM procedure gives better execution contrasted with the conventional PSPWM method (the

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

zero intersections of voltage references can be put self-assertively regardless of zero intersections of the stage moved transporters). Further, as the proposed procedure is a transporter based plan, synchronization in a profoundly powerful circumstance like field arranged control can be accomplished with a lot lesser computational unpredictability contrasted with the plans of [8], [20], [21] and so on. Be that as it may, with the expansion in the quantity of HBridges and p the consonant profile is practically like a customary PSPWM system [22]-[25].

III.EXPERIMENTAL RESULTS

Thesynchronization methodology forthe CHBMLIs is checked withathree stage squirrel confine enlistment engine driveparameters are givenin APPENDIX worked in open circle V/f mode, whichis provided fromafivelevelthree stage CHBMLI research facility model. The dc-interface voltage Vdc of every H-Bridge is kept up at 100V during the trial to work the engine at half of the appraised voltage. Both the conditions for keeping up quarter wave symmetry in the resultant shaft voltage designs VHB, as talked about in Section II, are tried tentatively. For exploratory confirmation, the proportion p is maintained at 3 in control to demonstrate the shaft voltage heartbeat designs unmistakably. Fig.11.(a) demonstrates that the zero intersections of bearer CHB1 harmonizes with the zero intersections of voltage references R1 and R2. Fig.11.(b) demonstrates that the individual extension voltage waveforms VHB1 and VHB2 alongside the resultant post voltage waveform VHB keep up half wave symmetry and quarter wave symmetry. Fig.11.(d) demonstrates that the zero intersections of voltage references R1 and R2 are put equidistantly inthe middle of the zero intersections of bearer CHB1 and CHB2. Fig.11.(e) demonstrates theindividual scaffold voltages VHB1 and VHB2 andresultant post voltage VHB. It very well may be seen thatthe individual extension voltages keep up halfwave symmetry, however not quarterwave symmetry, though resultant shaft voltage waveform keeps up halfwavesymmetry and quarterwavesymmetry. Fig.11.(c) and (f) demonstrate thatthe three stage symmetry is kept up among three stage shaft voltagewaveforms.

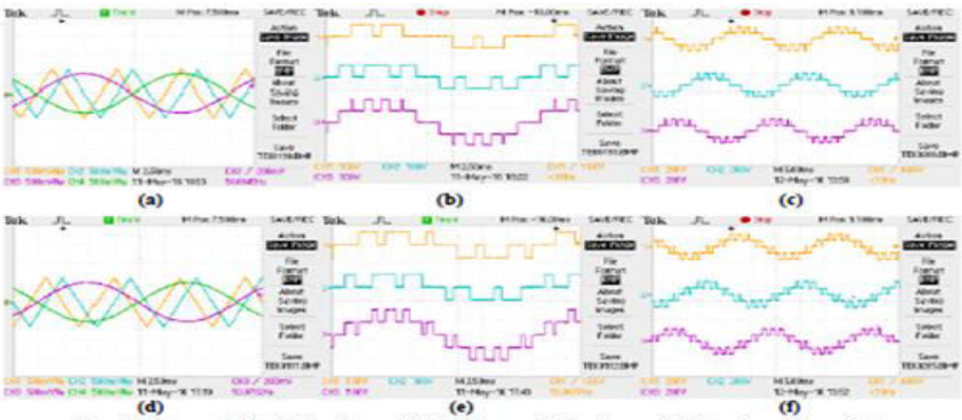

Fig. 11.(a) and (d) Ch.1:-C_{HB1}, Ch.2:-C_{HB2}, Ch.3:-R_1 and Ch.4:-R_2; (b) and (e) Ch.1:-V_{HB1}, Ch.2:-V_{HB2} and Ch.3:-V_{HB} and (c) and (f) Ch.1:-V_{RO}, Ch.2:V_{BO} and Ch.3:-V_{YO} when (i) the zero crossings of voltage references are in phase with the zero crossings of carrier C_{HB1} and (ii) the zero crossings of voltage references are placed at the midpoint of the positive zero crossings of carriers C_{HB1}& C_{HB2} for $f_c=3f_s$ with a modulation index of 0.8 and f_s=50Hz.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

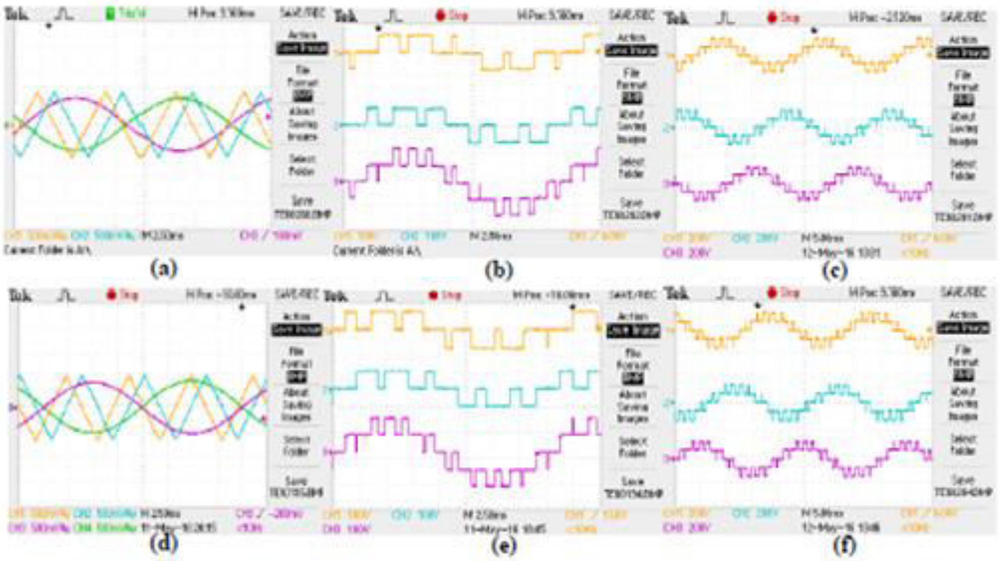

Fig. 12.(a) and (d) Ch.1:-C_{HB1}, Ch.2:-C_{HB2}, Ch.3:-R_1 and Ch.4:-R_2; (b) and (e) Ch.1:-V_{HB1}, Ch.2:-V_{HB2} and Ch.3:-V_{HB} and (c) and (f) Ch.1:-V_{RO}, Ch.2:V_{BO} and Ch.3:-V_{YO} when (i) the zero crossings of voltage references are placed at $+\pi/12$rad with respect tothezero crossings of carrier C_{HB1} for $f_c=3f_r$ with a modulation index of 0.8 and $f_r=50$Hz and (ii)for $f_c=160$Hz with a modulation index of 0.8 and $f_r=50$Hz.

So as look at the proposedPSPWM system, the analysis is finished withtwo arrangements of bearers CHB1&CHB2 wherethe zero intersections of voltage references, R1&R2 are put at an edge of +π/12 radwith deference tothe zero intersection of CHB1. The proportion p is kept at 3. Thiscondition guarantees the three stage symmetryandhalf wave symmetry. In any case, quarterwave symmetryisnot kept upFig.12.(a) demonstrates the previously mentioningconditions for voltagereferences, R1&R2 and bearers CHB1 and CHB2. Fig.12.(b) demonstrates thatthe individual scaffold voltages VHB1 and VHB2 alongside resultant extension voltage VHB keep up halfwave symmetry withoutkeeping up quarter wavesymmetry. Fig.12.(c) demonstrates thethree stage shaft voltages keep up three stage symmetry. So also, a couple of transporters CHB1 and CHB2 having recurrence of 160Hz offbeatPWMare utilized to produce similar waveforms. The outcomes are appeared inFig.12.(d),. It tends to be seen thattheindividual scaffold voltages alongside theresultant extension voltage don't keep up halfwavesymmetry, quarter wave symmetry or three stage symmetry. Duringthe examination, the regulation file ofthevoltagereferences is kept at 0.8witha recurrence of 50Hz. The symphonious ranges of linevoltages (VRY) with&without waveform symmetriesandsynchronization are analyzed inFig.13Fig.14.Fig.13.(b) and demonstrate symphonious range of linevoltage VRY which isthe aftereffect of keeping up quarter wavesymmetry for oneofthe conditions referenced in TABLEII. Fig.14.(b) demonstrates the consonant range ofthelinevoltage VRY, whenthere is no QWS presentamong the post voltagewaveform. The consonant ranges of fromeven request voltage music, asthe post voltagewaveform looks after HWS. The consonant ranges ofFig.13.(b)Fig.13.(d) inFig.14.(b) demonstrate thatthelinevoltageis free fromtriplen request voltage music. Henceforth, thethree stage symmetryis kept up among thethree stage shaft voltagewaveforms. TheWTHD of line voltage VRY for the over threecases are

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

practically equivalent. Theminor contrast is now appeared inFig.10. Fig.14.(d) demonstrates thatthe consonant range ofthelinevoltage VRY contains a little dc balance for160Hz stage moved bearers. This DC balance is seen inthe symphonious range, asthe consonant ranges areplottedforone central cycle. Foran offbeat bearer, the post voltagewaveform alongside the linevoltage waveform arenot intermittent thinking of one as central time of the voltagereference. Be that as it may, if the symphonious ranges are plotted dependent on an information of a timespan inwhich both the crucial andthe transporters complete whole number of cycles, at that point thisDC balance won't be seen inthe consonant ranges of post voltage just as linevoltage. Or maybe, it will show up assubharmonic segment. The subharmonic recurrence is awful fordrive's application, since it might coordinate with themechanical reverberation recurrence of the driveshaft. Additionally, itis a typical practiceto utilize inverter yield channels for driveswithlong separation between the converterandtheengine. It very well may be seen thatthe recurrence range with synchronized bearer areof concentrated nature, while, with nonconcurrent transporter areof disseminated nature. Consequently, structure of yield channelis increasingly affordable forsynchronized transporter based methodology wherethe proportion betweenthe bearer recurrence andthe central recurrence (p)is exceptionally low. Additionally, nonconcurrent bearers request voltage sounds are seen inthelinevoltage waveform, because of the nonappearance HWSamong post voltagewaveform. Some test resultsare additionally takenfor a three stage fivelevelCHBMLI encouraged squirrel confine enlistment engine drive withp=6andfs=50Hz. This analysis is done so as to demonstrate thattheproposedPSPWM strategy is likewise substantial for bearers having a recurrence proportion p beingeven. Fig.15.(a) and Fig.16.(a) demonstrate theindividual scaffold voltages alongside theresultant extension voltage of a solitary stage fivelevelCHBMLI with the conditionsfor keeping up QWSamong shaft voltage VHB (as referenced inTABLE-II). InFig.15.(a) demonstrates thattheindividual extension voltages alongside theresultant scaffold voltage keep up HWS&QWS, whenthe zero intersection of one bearer agrees withthe zero intersection of voltagereferences. Fig.16.(a) demonstrates the individual extension voltages don't keep up QWS however the resultant scaffold voltage keeps up QWSwhenthezero intersection of the voltagereferences are set atthe midpoint ofthe zero intersections ofthe bearers. InFig.15,Fig.16 likewise demonstrate theFFT ranges of post voltageVRO and line voltage VRY forp=6andfs=50Hz with a balance record of0.8. The consonant ranges of shaft voltage VRO inFig.15.(b) and Fig.16.(b) demonstrate thateven request voltage music are missing. It implies the post voltagewaveform VRO looks after HWS. The consonant ranges of linevoltage VRY inFig.15.(d)&Fig.16.(d) demonstrate the triplen music are missing fromthe line voltagewaveform VRY. This demonstrates the three stage shaft voltage waveforms keep up3stage symmetry. TheTHDofallwaveformsare determined and WTHDis additionally appeared for line voltage VRY. TheWTHDofthelinevoltage VRY demonstrates that the impact of lower request voltage music is indistinguishable in both the conditions referenced inTABLE-II. Thisoccurs likewise withhigherp, the WTHDs of line voltages are practically

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

indistinguishable independent ofthe various conditionsfor looking after QWS

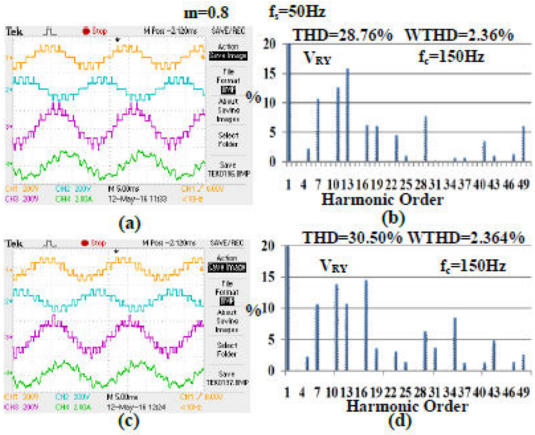

Fig. 13.(a) and (c) Ch.1:- VRO, Ch.2:- VYO, Ch.3:- VRY and Ch.4:- iR; (b) and (d) Harmonic range of VRY for (I) the zero intersections of voltage references are in stage with the zero intersections of bearer CHB1 and (ii) the zero intersections of voltage references are set at the midpoint of the positive zero intersections of transporters CHB1& CHB2 for fc=3fs with a tweak record of 0.8 and fs=50Hz.

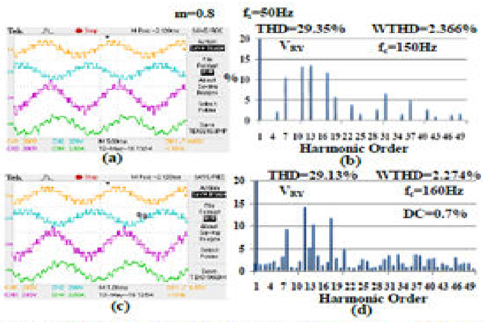

Fig. 14.(a) and (c) Ch.1:-V_{RO}, Ch.2:-V_{YO}, Ch.3:-V_{RY} and Ch.4:-i_R; (b) and (d) Harmonic spectrum of V_{RY} for (i) the zero crossings of voltage references are placed at $+\pi/12$ rad with respect tothe zero crossings of carrier C_{HB1} for f_c=3f_s and (ii)f_c=160Hz with a modulation index of 0.8 and f_s=50Hz.

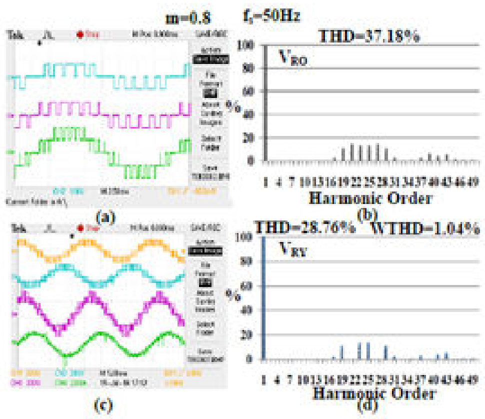

Fig. 15.(a) Ch.2:- V_{HB1}, Ch.3:- V_{HB2} and Ch.4:- V_{HB}; (b) Harmonic spectrum of V_{RO}; (c) Ch.1:-V_{RO}, Ch.2:-V_{YO}, Ch.3:-V_{RY} and Ch.4:-i_R and (d) Harmonic spectrum of V_{RY} when the zero crossings of voltage references are in phase with the zero crossings of carrier C_{HB1} for f_c=6f_s with a modulation index of 0.8 and f_s=50Hz.

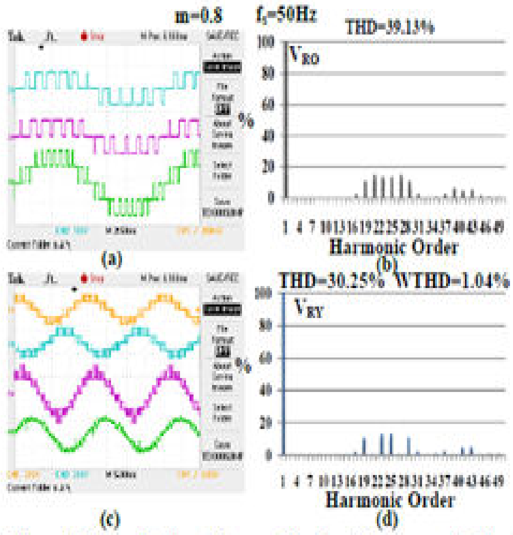

Fig. 16.(a) Ch.2:- V_{HB1}, Ch.3:- V_{HB2} and Ch.4:- V_{HB}; (b) Harmonic spectrums of V_{RO}; (c) Ch.1:- V_{RO}, Ch.2:-V_{YO}, Ch.3:-V_{RY} and Ch.4:-i_R and (d) Harmonic spectrums of V_{RY} when the zero crossings of voltage references are placed at the midpoint of the zero crossings of carriers C_{HB1}& C_{HB2} for f_c=6f_s with a modulation index of 0.8 and f_s=50Hz.

In Fig.17Fig.18 are taken withthe assistance ofathree stage fivelevelCHBMLI nourished squirrel confine enlistment engine drive. Fig.17 likewise demonstrates the outcomes keeping up shaft voltagewaveform for twofold fell HBridgeswithp=9. Henceforth, the conditions organized in TABLEII, are legitimate for any 3n (where n=1, 2, 3,..... and so on.) transporter. Fig.18.(b) demonstrates the progress of the R-Phase current iR during the moving between the synchronous transporters havingp=9top=3. Fig.18.(b) demonstrates a smooth progress betweenthe bearers having p=9 to p=3, as no critical homeless people are seen in engine current iR. The consequences of the positivezero intersections of bearers CHB1 and CHB2. This methodology chosen exploratory confirmation asthe power taken care of byeach extension is equivalent for lowerp and higher estimations of adjustment files as talked about insegmentII.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

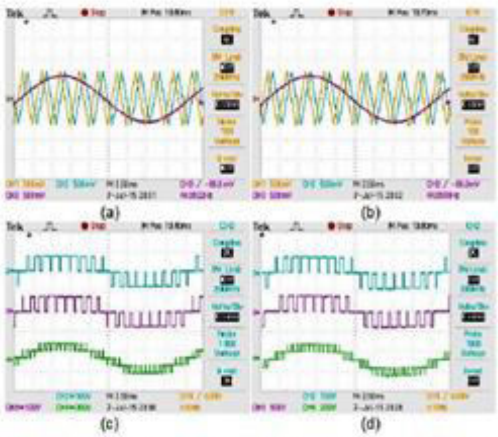

Fig. 17.(a) and (b) Ch.1:-C_{HB1}, Ch.2:-C_{HB2}, Ch.3:-R_1 and Ch.4:-R_2 and (c) and (d) Ch.1:-V_{HB1}, Ch.2:-V_{HB2} and Ch.3:-V_{HB} when (i) the zero crossings of voltage references are placed at the midpoint of the positive zero crossings of carriers C_{HB1}& C_{HB2} and (ii) the zero crossings of voltage references are in phase with the zero crossings of carrier C_{HB2} for f_c=9f_s with a modulation index of 0.9 and f_s=45Hz.

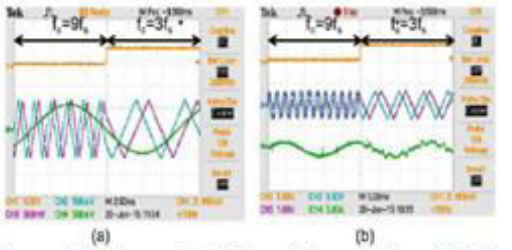

Fig. 18.(a) Ch.1:-Transition signal,Ch.2:-C_{HB1},Ch.3:-C_{HB2} and Ch.4:-R-Phase voltage reference and (b) Ch.1:-Transition signal,Ch.2:-C_{HB1},Ch.3:-C_{HB2} and Ch.4:-i_R during the transition fromp=9 to p=3.

So as to look at the proposedPSPWM procedure for highernumber of fell H-Bridgesthe test is additionally performed with aninelevel fell H-Bridge staggered inverterFig.19 demonstrates the outcomes fortwo potential mixes of arrangement of zero intersections of voltagereferences with deference tothepositivezero intersections of the bearersFig.19.(a)(b) demonstrate the waveforms ofindividual scaffold voltages alongside the resultant extension post voltage separately, when thezero intersection of voltagereference corresponds with the positive zero intersection ofoneof the bearers. Fig.19.(d) and (e) demonstrate thewaveforms of individual extension voltages alongside the resultant scaffold shaft voltageseparately, when thezero intersection of voltagereferences is put atthe midpoint of the positivezero intersections oftwo neighboring transporters. The consonant ranges of post voltagewaveform VRO are appeared inFig.19.(c)(f) individually. The even request sounds wiped out from the symphonious range ofthe post voltagewaveform, as every one of the waveforms look after HWS. It tends to be expressed that, withthe expansion inthe quantity of voltagelevels, the symphonious range is moved tohigher requests and their extent likewise descends. Every one of the plots are accomplished fora regulation list (m) of 0.8 at a post voltagereference recurrence (fs) of 50Hz andp=3.

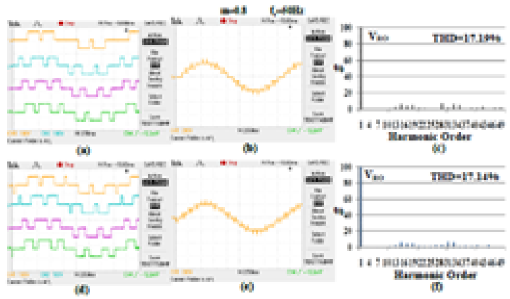

Fig. 19.(a) and (d) Ch.1:-V_{HB1}, Ch.2:-V_{HB2}, Ch.3:-V_{HB3} and Ch.4:-V_{HB4}; (b) and (e) Ch.1:-V_{HB} and (c) and (f) Harmonic spectrum of V_{HB} when (i) the positive zero crossing of one carrier co-incides with the zero crossing of fundamental voltage reference and (ii) the zero crossing of fundamental voltage reference is placed at the midpoint of two adjacent carriers with a modulation index of 0.8, f_s=50Hz and p=3 for a single phase nine level CHBMLI.

IV.CONCLUSION

Thispaper exhibits legitimately the potential spots ofzero crossing points ofthe bearers withrespecttothe zero convergences of voltagereferencesforthe CHBMLIs using thePSPWM methodology for keeping up threephase symmetry, halfwave symmetry and quarter wave symmetry. Threephase and halfwave symmetries are kept up among theH-Bridge shaft voltagewaveforms for any circumstance of zero crossing point of carrierwith reverence tothe zero convergence ofthe voltage references, as long as transporter repeat is3n time the pivotal repeat withnbeing any entire number (even/odd). In any case, the spots zero crossing points ofthe transporters with reverence tothe0-convergences of voltagereferences are huge for keeping up quarterwave symmetry amongthe post voltagewaveforms. Thisis consistently perused inthisarticle for single and two fell H-Bridgesand summed up forx number of fell HBridges. The assessments likely checked withthe help ofathreephase five levelCHBMLI investigate office model andtheresultsare shown.

REFERENCES

1. J.Rodriguez;S.BernetBin Wu; J.O.Pontt and S.Kouro, Multilevel Voltage-Source-Converter Topologies for Industrial Medium-Voltage Drives,‖ IEEE Transactions on Industrial Electronics , vol.54, no.6, pp.2930-2945, Dec. 2007.
2. S.Kouro; M.Malinowski; K.Gopakumar; J.Pou; L.G.Franquelo; Bin Wu; J.Rodriguez; M.A.Perez and J.L.Leon, Recent Advances and Industrial Applications of Multilevel Converters,‖IEEETransactionsonIndustrial Electronics, vol.57, no.8, pp.2553-2580, Aug. 2010.
3. G.NarayananV.T.Ranganathan, Two epic synchronized busclamping PWM procedures dependent on space vector approach for high power drives,‖ IEEE
4. A.R.Beig; S.Kanukollu.;K.AlHosani and A.Dekka, Space-VectorBasedSynchronizedThree-Level DiscontinuousPWM for Medium-Voltage HighPowerVSI‖IEEE Transactions onIndustrial Electronics, vol. 61,no.8,pp. 3891 – 3901, Aug. 2014.
5. G.Narayanan, SynchronisedPulsewidthModulationStrategies dependent on SpaceVectorApproachfor Induction MotorDrives,‖ Ph.D. proposition, Indian InstituteofScience, Bangalore, India, 1999.
6. GuiseppeS. BujaGoivanniB.Indri, Optimal Pulsewidth Modulation for Feeding AC Motors‖,IEEE Trans.Ind.Appl.,vol.IA13,no.1,pp.38-44,Jan./Feb.1977.
7. A.EdpugantiA.K.Rathore, Optimal Low-Switching FrequencyPulsewidth Modulation of MediumVoltage Seven-Level Cascade-5/3H Inverter,‖IEEETrans.Power.Electron ,vol.30, no.1, pp.496-503, Jan.2015.
8. A.K.RathoreJ.HoltzT.Boller, SynchronousOptimalPulsewidth Modulation for Low-Switching-FrequencyControl of MediumVoltage Multilevel Inverters,‖IEEE Transactions on IndustrialElectronics,, vol.57, no.7, pp.2374-2381, July 2010.
9. J.HoltzandN.Oikonomou, Synchronous Optimal Pulsewidthodulation and StatorFluxTrajectoryControlforMedium-Voltage Drives,‖IEEETransactionsonIndustry Applications,vol.43, no.2,