ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A novel DTC scheme of Control for Three Phase Cascaded H-bridge Converter based Induction Machine Control

T.Kalyani
M.Tech Student (PE)
Sri Venkateswara Engineering College,
Suryapet, Nalgonda(Dt),
Telangana State, India

R.Suresh
Sr. Assistant Professor (EEE)
Sri Venkateswara Engineering College,
Suryapet, Nalgonda(Dt),
Telangana State, India

Abstract: ***Here, in this paper presents have conical out the applications of traditional inverters, basically in high-voltage and high-power approach. In modern years, multilevel inverters are stylish increasingly favoured for high-power advantages due to their upgrade harmonic outline and improved power ratings. Many studies have been announced in the information on multilevel inverters schemes, control strategy and more Advantages. Although there are more of researches that basically consider or improved the characteristics of induction motor drives related with three-phase multilevel inverter. Here in this paper explains then a differentiate process of study for a back to back H-bridge multilevel direct torque control (DTC) regulate induction motor drive. In this section, symmetrical also asymmetrical configuration of five- also seven-level H-bridge inverters are differentiate in order to observe an upgrade configuration with minimum switching losses and access output voltage quality. The convey out experiments viewed that an asymmetrical configuration produces unless sinusoidal voltages comes with very less distortion by, using few switching devices. Moreover, torque disturbances are mainly decreased.***

Key Words: The Method of Direct torque control (DTC), The induction motor concepts and multilevel inverters approach.

INTRODUCTION

Multilevel voltage-source inverter approaches are intensively learning for high-power applications and excellence drives for medium-voltage industrial purpose have become attainable. The Provision with a more number of output voltage magnitude have the potential to arrange waveforms with a superior harmonic scope and to bound the motor winding protection stress. Although, their improved more number of instruments tends to decrease the power converter inclusive more accuracy and efficiency. The different solutions with a less number of levels either used a rather more and exorbitant LC output filter to ultimate the motor winding protection stress, or can only be worm with motors that do working such stress. The different levels of voltage section have been taken after consider the real-power benefaction of the maximum voltage section.

The maximum power provided by peak voltage section is maintained under the load power. More concepts have been organized toward increasing the multilevel inverter. Some more studies allocate with innovative methodologies, such as back to back multilevel inverter, to advance the components more operation and the asymmetrical multilevel inverter to increases the output voltage design. Some more research mainly on developing improved control schemes or upgrading the voltage supplying inverter sections for performance in multilevel inverter. In some types of symmetrical multilevel inverter, more H-bridge cells are support by same voltages and hence more the arm cells provide similar output voltage stages. Although, if more the cells are not support by same voltages, the inverter flatter an asymmetrical only. In here inverter, the arm cells has various problems on the output voltage. Other methods are also possible; some are the neutral point clamped support by unlike capacitors. Asymmetrical multilevel inverter has been newly investigated. In all particular to learning that H-bridge method has been considerable and a different of selections of back to back cell numbers and dc-sources balance have been assume. The considerable pulse width-modulation scheme that supports the high-voltage state to operate at less frequency ranges the source-voltage collection. One of the techniques that have been worm by a main multilevel inverter processor is direct

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torque control (DTC), and that is identify today as a high-performance regulate scheme for ac drives. Many authors have considered the problem of increases the behaviour of DTC ac motors, basically by decreases the torque harmonics. Different methods have been considerable. Even Though these methods are well considerable for the traditional two-levels inverter, their restrained to a maximum number of stages is not informal. Here in this paper, a theoretical framework is worm to design a scheme consistent with hybrid back to back H-bridge multilevel inverter; symmetrical including asymmetrical arrangements are implemented and analogize. Experimental outputs procure for asymmetrical inverter-support induction motors affirm the more effective performance of the worn techniques, presenting more performances and very less torque ripples.

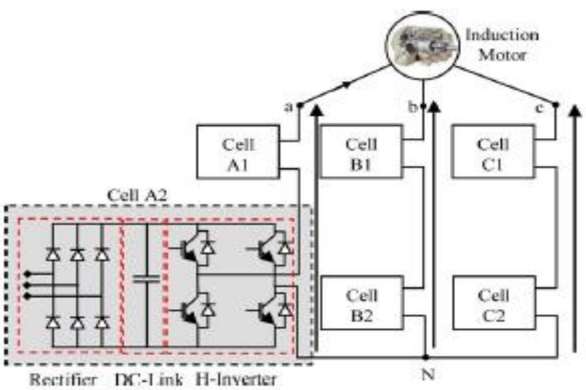

Fig. 1. Structure of two-cells cascaded multilevel inverter.

CASCADED H-BRIDGES STRUCTURE AND OPERATION

The cascaded H-bridge inverter provide of power translation cells, in that each one considerable by an outlying dc supply on the dc stage, in which can be procure from batteries source, fuel cells system and ultra-capacitors and series-attach on the ac stage. The advantage of this strategy is that the inflection, regulate, and maintenance demand of each bridge are modulation. It would be conic out that, dissimilar the diode-clamped inverter and flying-capacitor strategy, connection of dc supply are included for individual cell in each one phase. Fig. 1 shows a three-phase strategy of a cascade inverter connection with protection dc-voltage supply. An output phase-voltage waveform is procure by quantity the bridges output voltages

$$v_o(t) = v_{o,1}(t) + v_{o,2}(t) + \cdots + v_{o,N}(t) \qquad (1)$$

Here N is the number of cascaded connected bridges.
The inverter output voltage vo (t) can be obtained from the separately cells switching scheme

$$v_o(t) = \sum_{j=1}^{N} (\mu_j - 1)\, V_{\mathrm{dc},j}, \qquad \mu_j = 0, 1, \ldots . \qquad (2)$$

If all dc-voltage supply in Fig. 1 are same to Vdc, the inverter is then familiar as a symmetric multilevel inverter one. The efficient number of output voltage magnitudes in symmetric multilevel inverter connection is same as to the cells numbers by

$$n = 1 + 2N \qquad (3)$$

For example, Fig. 2 shows typical waveforms of Fig. 1 multilevel inverter connection with two dc supply (five-levels output connection). The peak value output voltage Vo, Max is that

$$V_{\mathrm{o,MAX}} = N V_{\mathrm{dc}}. \qquad (4)$$

To allocate a large number of output schemes without improving the number of inverters stages, asymmetric multilevel inverters connection could be used.
it is provide to select the dc-voltages supply following to a geometric development with a factor of 2 or 3. For N of such that cascade connection of inverters, one could be improved the following definite voltage magnitudes

$$\begin{cases} n = 2^{N+1} - 1, & \text{if } V_{\mathrm{dc},j} = 2^{j-1} V_{\mathrm{dc}}, \quad j = 1, 2, \ldots, N \\ n = 3^N, & \text{if } V_{\mathrm{dc},j} = 3^{j-1} V_{\mathrm{dc}}, \quad j = 1, 2, \ldots, N. \end{cases} \qquad (5)$$

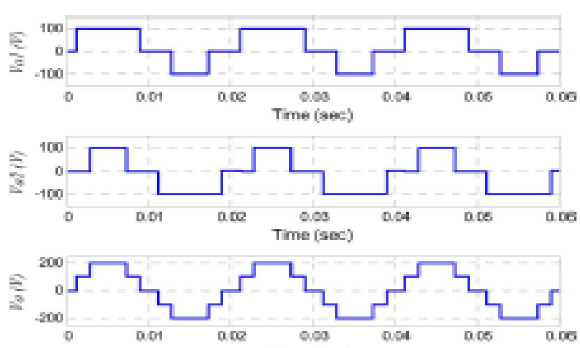

Fig. 2. Symmetric multilevel inverter with five-levels output voltage synthesis.

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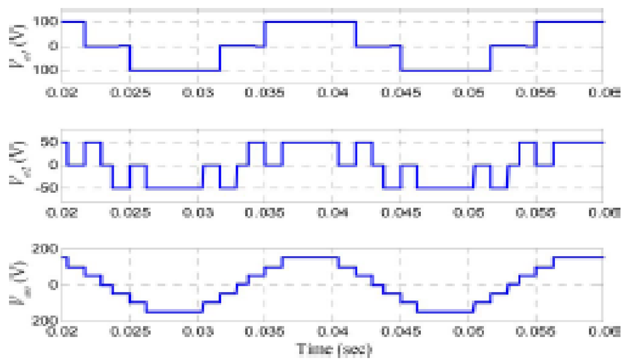

Fig. 3. Asymmetric multilevel inverter with seven-levels output voltage synthesis.

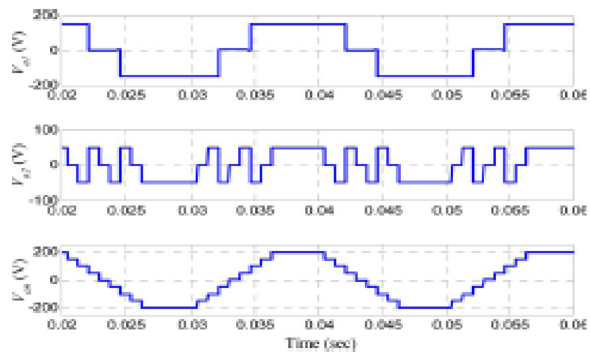

Fig. 4. Asymmetric multilevel inverter with nine-levels output voltage synthesis.

For example, Figs. 3 and 4 shows a typical waveforms of Fig. 1 multilevel connection of inverter with appropriately, two dc supplies (Vdc and 2Vdc) (seven-levels connection output) and two dc supplies (Vdc and 3Vdc) (nine-levels connection of output).

TABLE I
COMPARISON OF MULTILEVEL INVERTERS

	Symmetrical inverter	Asymmetrical inverter	
		Binary	Ternary
N	$2N+1$	$2^{N+1}-1$	3^N
DC sources number	N	N	N
Switches number	$4N$	$4N$	$4N$
$V_{o,MAX}$ [pu]	N	2^N-1	$(3^N-1)/2$

The peak output voltage of these N cascaded connections of multilevel inverters is

$$V_{o,\mathrm{MAX}} = \sum_{j=1}^{N} V_{\mathrm{dc},j}. \tag{6}$$

Equation (6) can be rewritten as

$$\begin{cases} V_{o,\mathrm{MAX}} = (2^N - 1)\, V_{\mathrm{dc}}, \\ \quad \text{if } V_{\mathrm{dc},j} = 2^{j-1} V_{\mathrm{dc}}, \qquad j = 1, 2, \ldots, N \\ V_{o,\mathrm{MAX}} = \left(\dfrac{3^N - 1}{2}\right) V_{\mathrm{dc}}, \\ \quad \text{if } V_{\mathrm{dc},j} = 3^{j-1} V_{\mathrm{dc}}, \qquad j = 1, 2, \ldots, N. \end{cases} \tag{7}$$

By comparing (3) to (7), it could be follow that asymmetrical multilevel connection inverters can produce maximum voltage levels and more maximum output voltage with the equally number of stages. Table I condense the number of levels, switches, dc supply and maximum obtainable output voltages for restrained cascaded connection of multilevel inverters. Improved the number of stages produce more stages hence, the output voltage would be of maximum resolution and the referral sinusoidal output improved voltage could be better produced. Among them the n3 switching schemes of n-level inverter, there is n zero stages, where zero output voltages are process. Among them the (n3−n) nonzero endure states, there are individual states and mutual stages. The isolated states produce voltage vectors In that cannot be procure by any other stages. The mutual position on the other side, produce a set of some output voltages that could be produced by some dissimilar mutual position or schemes.

The equivalent mutual stages divide the equally voltage vectors. The n-level number of inverter have [(n − 1)3 − (n − 1)] nonzero mutual stages. The voltage vectors of the five-level connection of inverter are shown in Fig. 5. The number of definite voltage vectors procure from n-level number of inverter is [n3 − (n − 1)3]. The existing of identical mutual stages has normally been worm to decrease the switching losses. Nonetheless, the alternative mutual stages could be exchange by some one of these stages and the other stages could be considered unwanted. There are (n − 1)3 useless stages in the n-level symmetrical connection of H-bridge multilevel inverter.

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INDUCTION MOTOR DIRECT TORQUE CONTROL

The DTC is one of an different method to flux-oriented control method. Although, in the excellence type, important torque harmonics is acquire even though at maximum sampling frequencies. Furthermore, the inverter switching frequency is constitutionally variable and hugely dependent on mainly torque and shaft speed. This provided torque ripples with variable frequencies and an hearing noise with disturbance strength more dependent on those mechanical parameters and specially grinding at less speed. The supplementary degrees of freedom produce by the multilevel connection of inverter should, accordingly, be utilize by the control scheme in order to decrease these drawbacks.

A.Nomenclature

Vs	Stator voltage vector.
Φs (φr)	Stator (rotor) flux vector.
Te	Electromagnetic torque.
Rs	Stator resistance.
Ls (Lr)	Stator (rotor) inductance.
Lm	Magnetizing inductance.
σ	Total leakage coefficient, σ = 1− L2m/LsLr
θsr	Angle between stator and rotor flux vectors.
p	Pole pair number.

B. Torque and Flux Estimation

The stator flux consideration vector of an induction motor is associated to the stator voltage and current vectors by using

$$\frac{d\phi_s(t)}{dt} = v_s(t) - R_s i_s(t) \qquad (8)$$

Prolong vs constant over a typical time interval and omit the stator resistance, the integration of (10) is

$$\Delta\phi_s(t) = \phi_s(t) - \phi_s(t-\Delta t) = \int_{t-\Delta t}^{t} v_s \Delta t. \qquad (9)$$

Equation (9) exhibit that the stator flux vector is immediately overdone by difference on the stator voltage considerable vector. On the opposite, the effect of vs over the rotor flux is filtrate by the rotor and stator losses of inductance and is, accordingly, not relative over a short-time outlook. So the stator flux could be change early when the rotor flux revolving slower, then angle between both vectors θsr can be regulated directly by vs. a graphical presentation of the stator and rotor flux driving behavior is shown in Fig. 6. The accurate relationship between stator and rotor flux that possession the magnitude of φs constant will provide a constant flux φr.

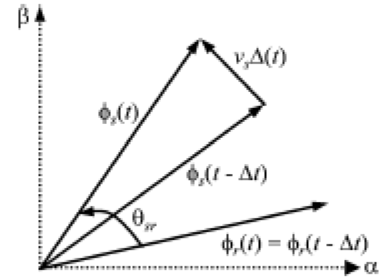

Fig. 5. Influence of *vs* over *φs* during a simple interval Δ*t*.

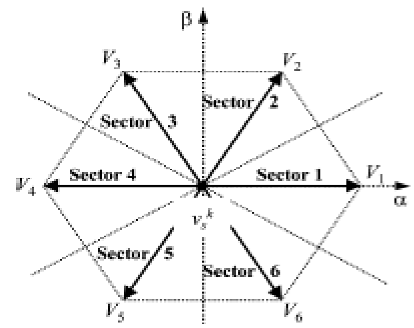

Fig. 6. Possible voltage changes Δvk s that can be applied from certain vks .

So the electromagnetic torque expand by an induction motor could be indicate by

$$T_e = \frac{3}{2} p \frac{L_m}{\sigma L_s L_r} \phi_s \phi_r \sin\theta_{sr} \qquad (10)$$

It result that change in θsr due to the activity of vs follows for direct and speedy change in the discribed torque. DTC utilize this principle to improve the induction motor crave torque characteristics, by supplying the proper stator voltage considerable vector to correct the flux approach.

C. Voltage Vector Selection

Fig. 6 show one of the 127 voltage vectors produce by the inverter at instant t=k, noted by vks (central dot notation). The next voltage consider vector, to be appeal to the load vk+1s, can be indicate by

$$v_s^{k+1} = v_s^k + \Delta v_s^k \qquad (11)$$

Where

$\Delta v_s^k = \{v_i | i = 1, \ldots, 6\}.$

Each vector vi be analogous to one corner of the basic hexagon shown in gray and by the dashed line in Fig. 6.
The task is to regulate which *vk*+1*s* will accurate the torque and flux retaliation, knowing the basic voltage vector *vks* , the torque and flux gains of errors *ekφ* and *ekT* , and the stator flux vector notation. Such that the following voltage vector *vk*+1*s* supplied to the load will remains be one of the six nearest vectors to the precursory *vk s* ; this will relieve the actuation problem and decrease high productive in torque response due to possible more changes in the referral. The Table II shows vector collection for the various sectors and comparators output (desired *φs* and *Te* calculations).

TABLE II
VOLTAGE-VECTOR-SELECTION LOOKUP TABLE

Sector	$\text{sign}(e_\phi^k, e_T^k)$			
	(+,+)	(+,–)	(–,+)	(–,–)
1	V_2	V_6	V_3	V_5
2	V_3	V_1	V_4	V_6
3	V_4	V_2	V_5	V_1
4	V_5	V_3	V_6	V_2
5	V_6	V_4	V_1	V_3
6	V_1	V_5	V_2	V_4

To contrivance the DTC of the induction motor support by a hybrid H-bridge multilevel connected inverter, one should control at each one of sampling period, the inverter switch logical stages as a functions of the torque and flux immediate values for the choosing of the space vector calculation in the α–β frame. The suggest regulate algorithm was allocate into two main tasks; those are independent and perform in cascade pattern.

1) *First task*: It goals at the regulate of the electromagnetic stage of the induction motor. The torque and flux immediate values and their differential will be considered into account for the space vector collection in the *α–β*. Once the space is selected, the phase ranges sequence can be chosen. To protect this task, one should reveal the space vector condition in the *α–β* frame (*Qk* at sampling considerable time *k*). The algorithm should be selected the next condition *Qk*+1 to be attain before next sampling express *k* + 1. in order to decrease voltage levels of magnitude. Only one step motion in the *α–β* frame is approve per sampling period consideration *Ts* . Hence, in the deficiency of inverter intensity, *Qk*+1 must coordinate with one of the six deviation of the fundamental hexagon centred at *Qk* (see in Table II).

2) *Second task*: It utilizes the degree of freedom affiliated to the multilevel connected topology to select the phase ranges sequences that integrate the voltage vector chosen lastly. There are many phase range sequences that are capable to produce the same vector shown in Fig. 6 this degree of latitude can, consequently, be utilize to reduce voltage stages of magnitude in proportion to one of the following standard: a) decrease the commutation number per spell; b) dispense commutations for the three-phases per spell; or c) select a vector which decrease the homo contrary voltage. This duty follows losses and torque harmonic minimization. Lastly, the arrangement of each phase will be choose and must be expert to produce the phase ranges.

CONCLUSION

Here, in this paper dispense with a differential study for a cascaded connection of H bridge multilevel pattern of DTC induction motor drive. So, symmetrical and asymmetrical configurations of five- and seven-levels of H-bridge inverters have been variables in order to calculate a perfect arrangement with less switching of losses and model output voltage qualities.

The convey out demonstration shows that an asymmetrical arrangements provides possibility sinusoidal voltages with hugely less distortion by using low switching action devices. It include, torque harmonics are mainly decreases: asymmetrical multilevel connection of inverter qualify a DTC method of solution for high-power range of induction motor drives Moreover not only due to the maximum voltage potential produce by multilevel connection of inverters, but important due to the decrease switching losses and the increases output voltage quality, which produce sinusoidal current lacking of output filter.

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AUTHOR DETAILS

THATIPAMULA KALYANI, *Pursuing M.tech (PE) from Sri Venkateswara Engineering College, Suryapet, Nalgonda(Dt),Telangana State, INDIA.*

REGATTI SURESH, *working as Sr.Assistant Professor (EEE) from Sri Venkateswara Engineering College, Suryapet, Nalgonda(Dt),Telangana State, INDIA.*