The design and analysis of multicarrier PWM based multilevel Z-source inverter fed induction motor drives with DTC

Presented by
S.MOHAMED YOUSUF M.E (Ph.D)
Assistant Professor
EEE Department
Sri Suramanya College of Engineering & Technology
Palani, Tamilnadu, India

Flow of presentation

- **Motivation**
- **Objective**
- **Multilevel inverters**
- **Impedance Source Inverter[ZSI]**
- **Modulation Schemes**
- **Block Diagrams**
- **Simulation Circuits & Results**
- **Development of Prototype Model**
- **References**

Motivation

- **The unique structure of multilevel inverters allows to reach from low level DC to high level AC voltages with low harmonics without the use of transformers.**

- **As the number of voltage levels increases, the harmonic content of the output voltage waveform decreases significantly.**

- **Higher voltage can be generated using the devices of lower rating.**

Objective

- **The main objective of the work is to analyze multilevel Z-source inverter fed AC drive using various advanced modulation schemes to obtain enhanced output waveform quality for induction motor.**

Multilevel inverters

- **In high-power and high-voltage applications, the two-level inverters have some limitations in operating at high frequency mainly due to switching losses and constraints of device ratings.**

- **Multi-level inverters are the preferred choice in industry for the application in High voltage and High power application**

- **As the number of voltage levels increases, the harmonic content of the output voltage waveform decreases significantly.**

Types of Multilevel inverters

1. **Neutral point clamped multilevel inverter**

   (or)

   Diode clamped multilevel inverter

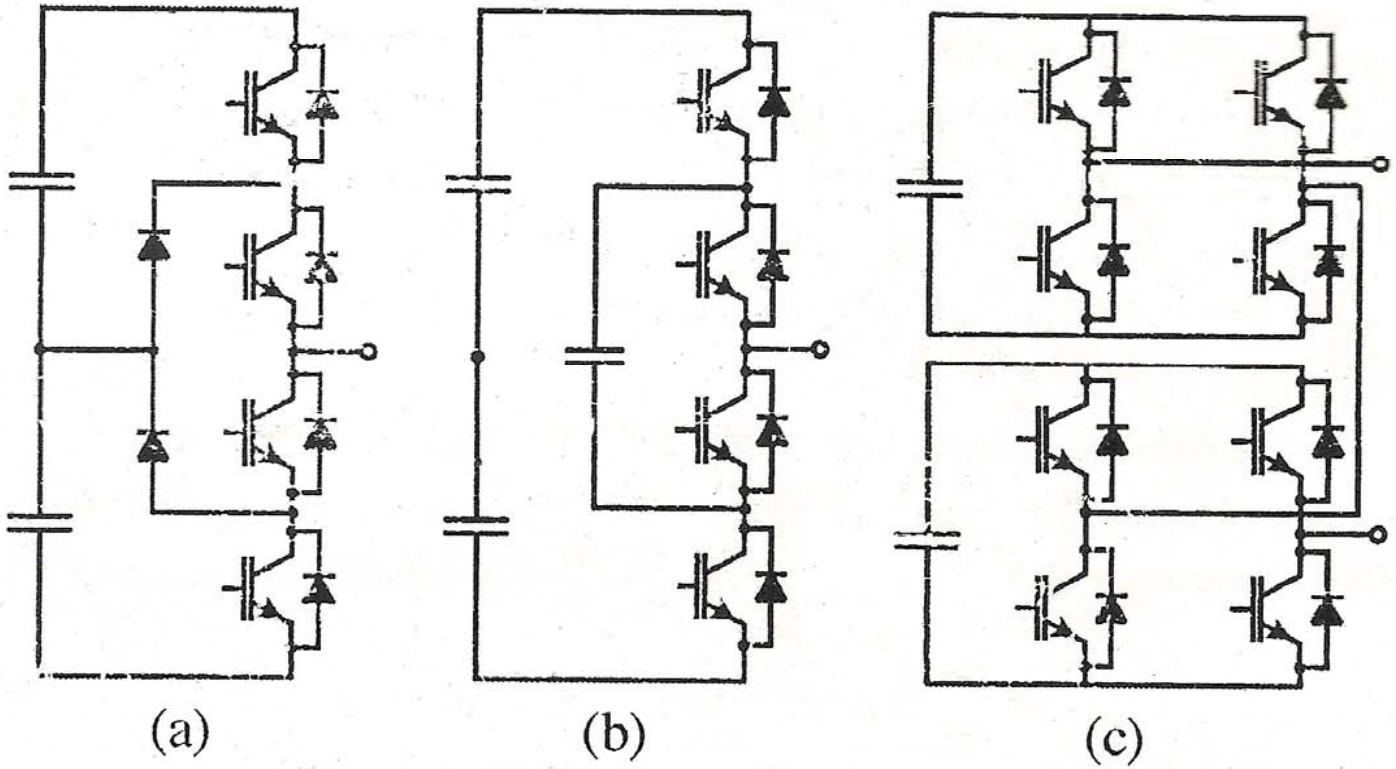
2. **Flying capacitor multilevel inverter**

3. **Cascaded H-bridge multilevel inverter**

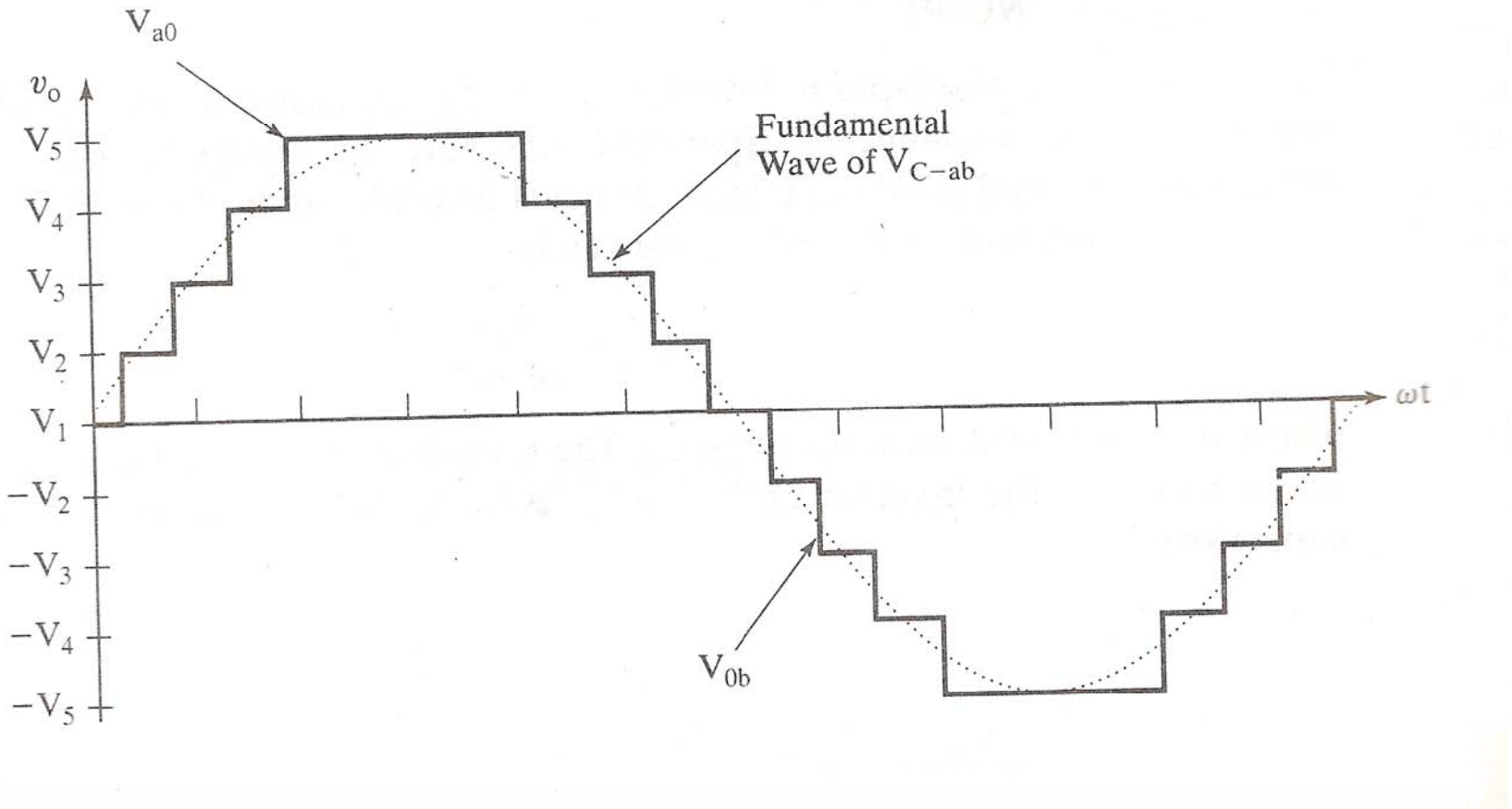
Comparison of Multilevel Inverters

Converter Type	Diode Clamp	Flying Capacitors	Cascaded Inverters
Main switching devices	(m-1)x2	(m-1)x2	(m-1)x2
Main diodes	(m-1)x2	(m-1)x2	(m-1)x2
Clamping diodes	(m-1)x(m-2)	0	0
Dc bus capacitors	(m-1)	(m-1)	(m-1)/2
Balancing capacitors	0	(m-1)x(m-2)/2	0

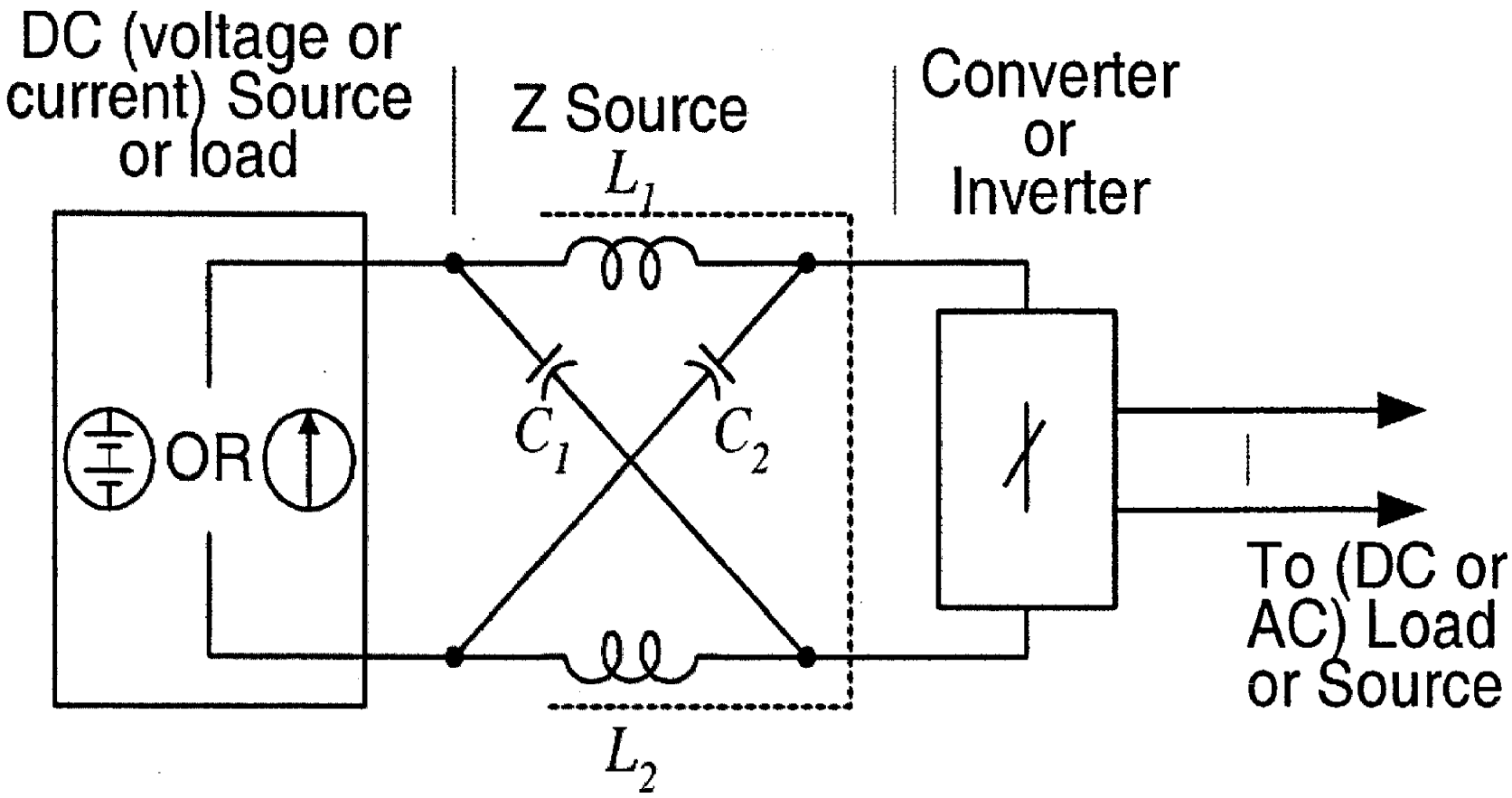
Types of Multilevel inverters



Output voltage of Multilevel inverter



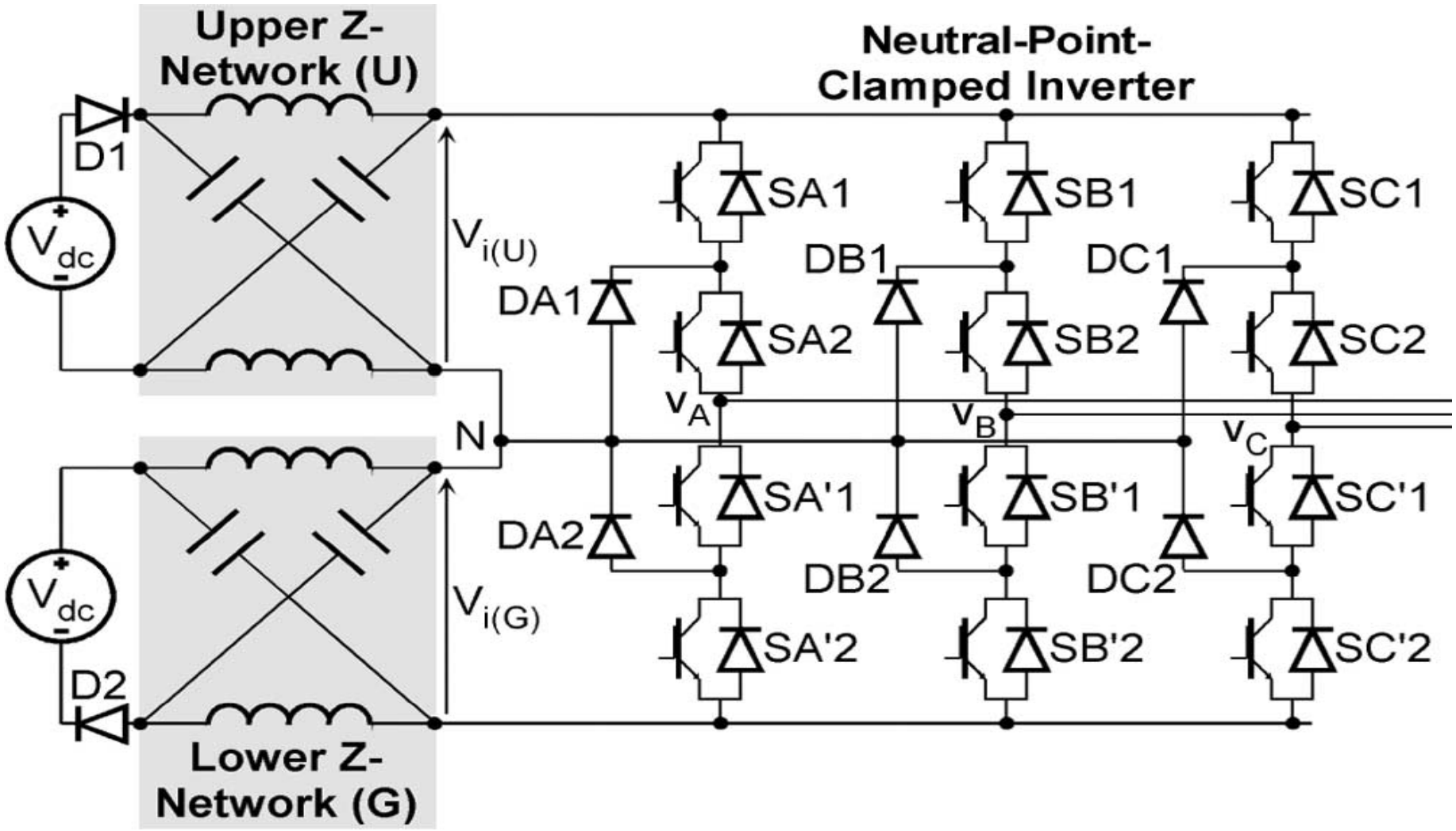
Impedance Source Inverter[ZSI]



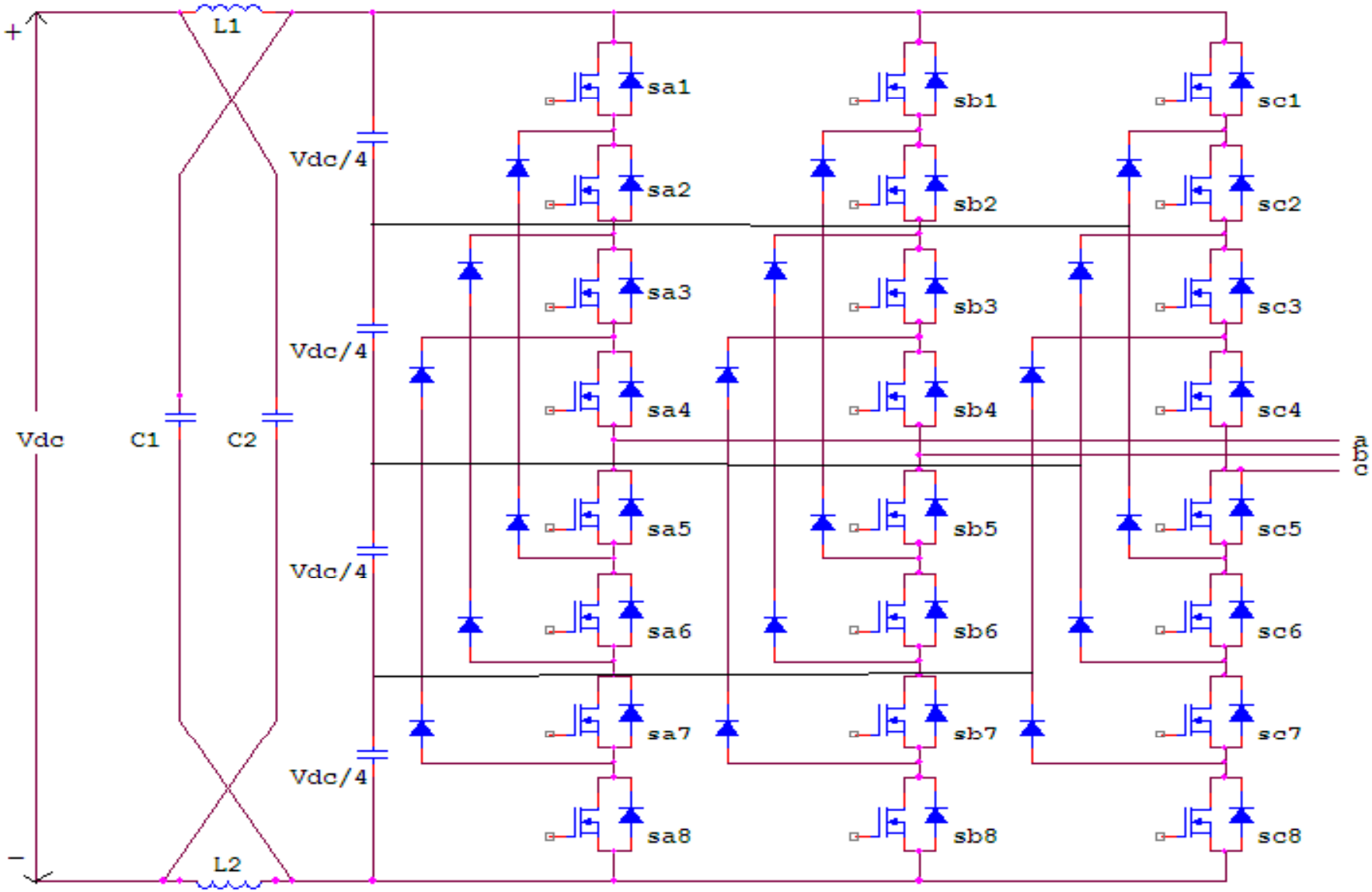
Impedance Source Inverter[ZSI]

- **It provides a novel power conversion concept.**
- **It overcomes the theoretical and conceptual barriers of traditional voltage source and current source inverters.**
- **It holds the additional X-shaped impedance network added between dc-source and multilevel inverter.**
- **The added impedance network is responsible for balanced inductive voltage boost, which are protect the inverter phase leg without causing damages to the semiconductor switches from sudden current surge by the Z-Source Inductor.**

Topology of Conventional Multilevel Z-source inverter



Topology of Modified Multilevel Z-source Inverter



Switching sequences of Modified Multilevel Z-source Inverter

Switching sequences								Terminal voltages
Sa1	Sa2	Sa3	Sa4	Sa5	Sa6	Sa7	Sa8	
1	1	1	1	0	0	0	0	2Vdc
0	1	1	1	1	0	0	0	Vdc
0	0	1	1	1	1	0	0	0
0	0	0	1	1	1	1	0	-Vdc
0	0	0	0	1	1	1	1	-2Vdc

Pulse Width Modulation Methods

The natural sampling techniques for a multilevel inverter are categorized into two and they are:

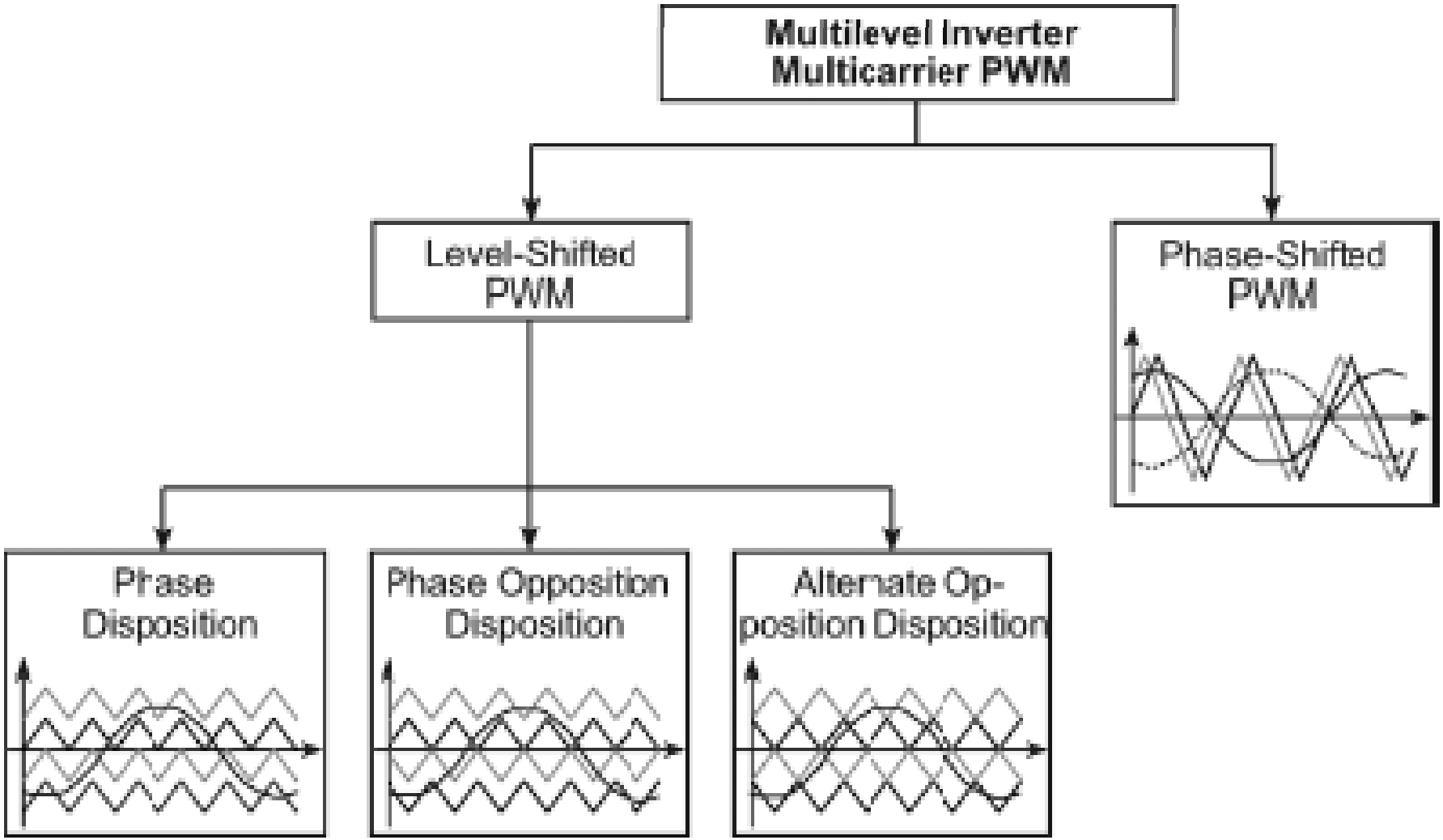
- **Single-Carrier SPWM (SCSPWM) and**
- **Sub-Harmonic PWM (SHPWM)**

  Sub-Harmonic PWM is an exclusive control strategy for multilevel inverters and has further classifications. They are:

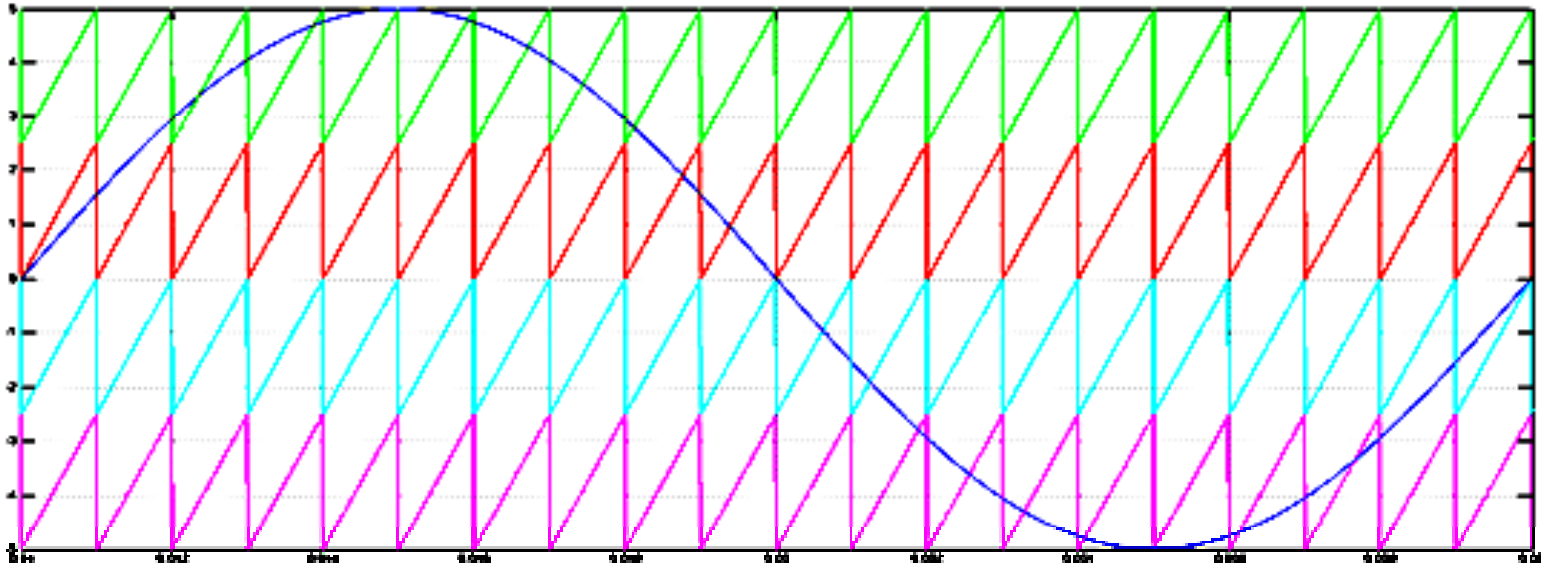
  1. **Phase Shifted Carrier PWM method (PSPWM)**
  2. **Level Shifted Carrier PWM method (LSPWM)**

- **Phase Disposition (PD)**
- **Phase Opposition Disposition (POD)**
- **Alternative Phase Opposition Disposition (APOD)**

Multicarrier PWM methods



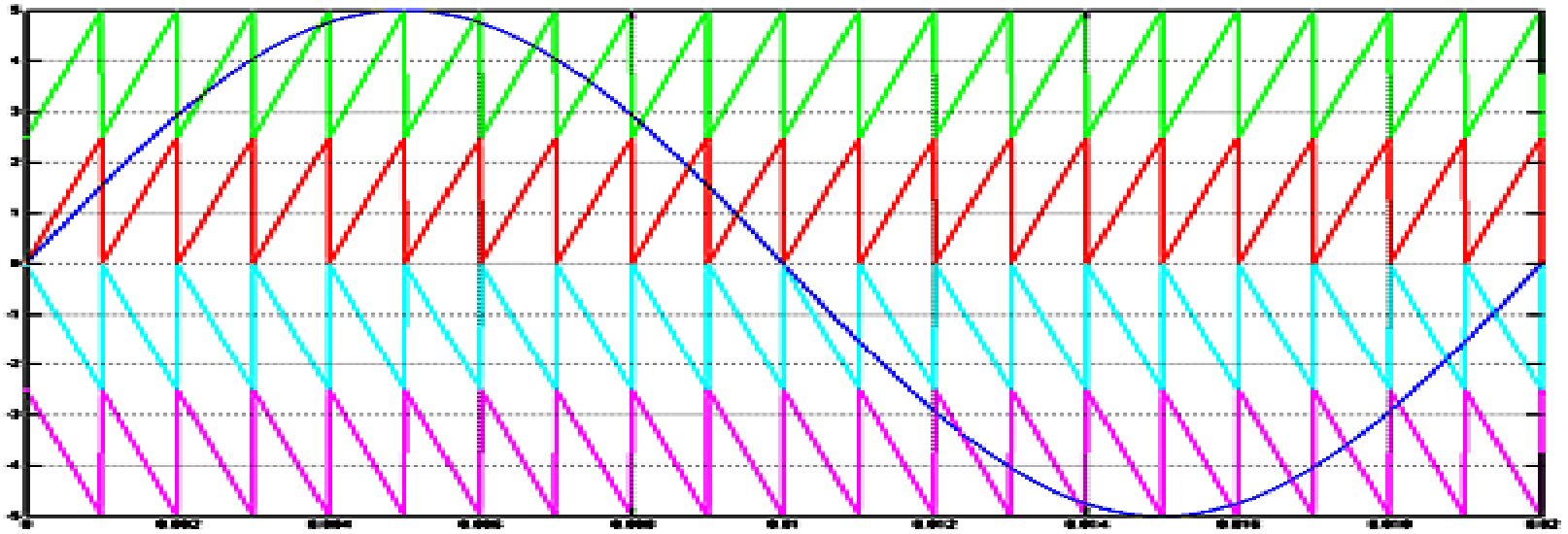
Multicarrier PWM methods (PDPWM)



The PDPWM incorporate L-l carriers, which all in phase consequently. The proposed five level topology take account of four carriers are settle in phase with one another and compared to reference wave.

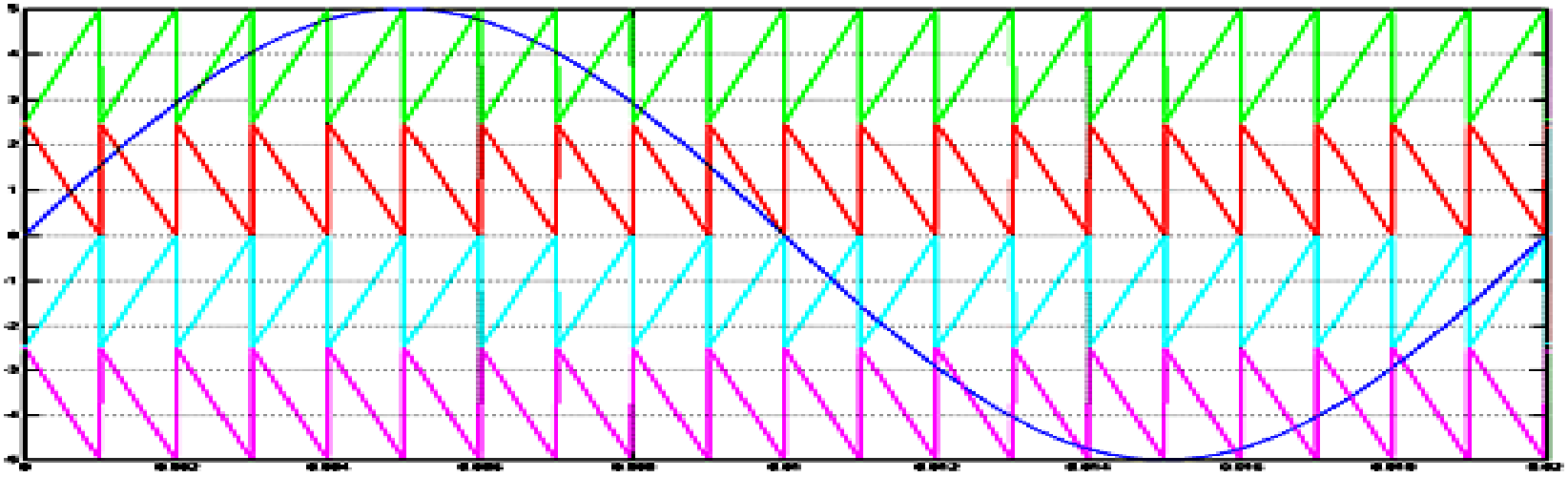
The PODPWM utilize L-l carriers which might be every carriers in phase above and below the zero position. At this point, all the carrier waves a

Multicarrier PWM methods (PODPWM)



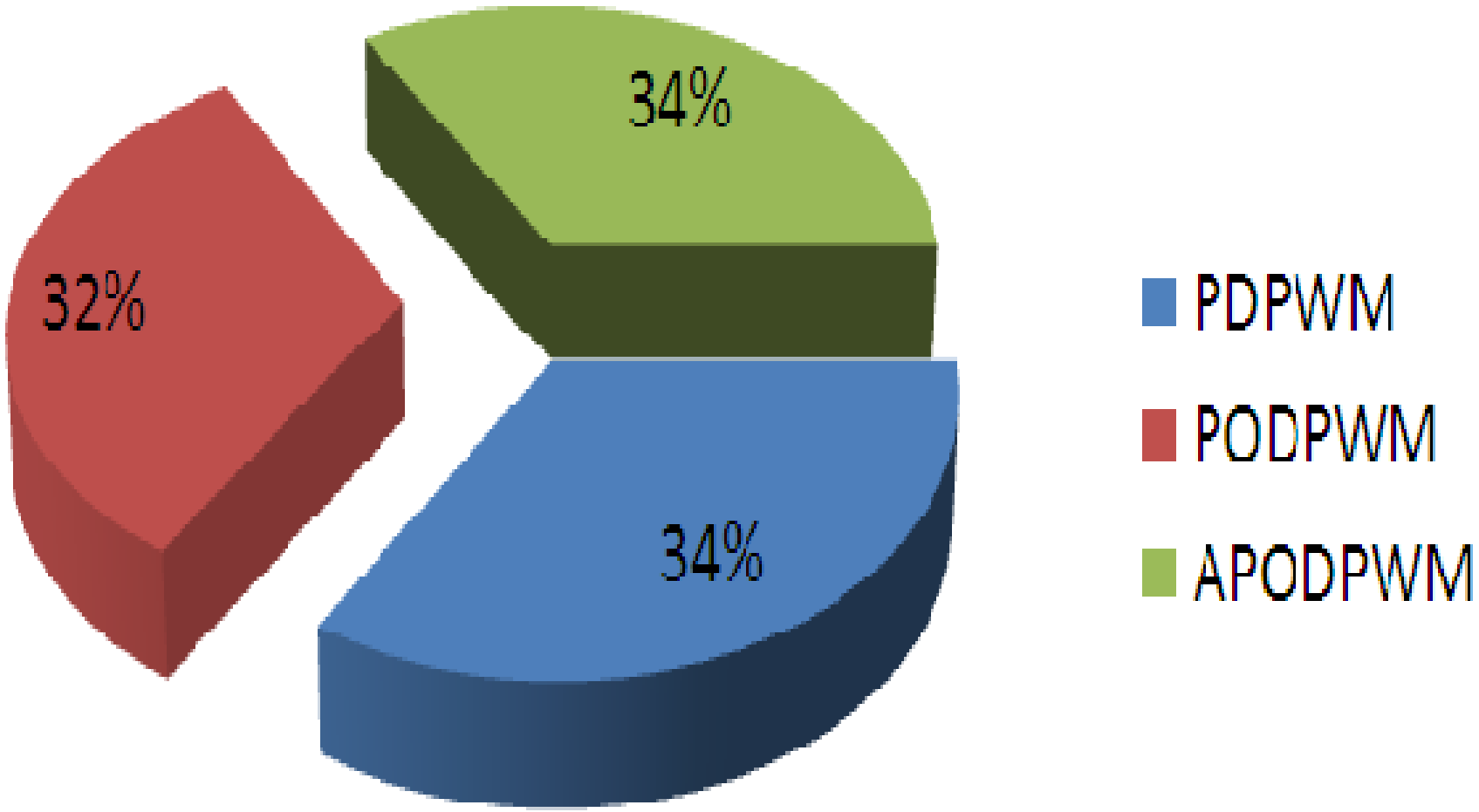
The PODPWM utilize L-l carriers which might be every carriers in phase above and below the zero position. At this point, all the carrier waves are phase shifted by 180° between the ones above and below zero position.

Multicarrier PWM methods (APODPWM)

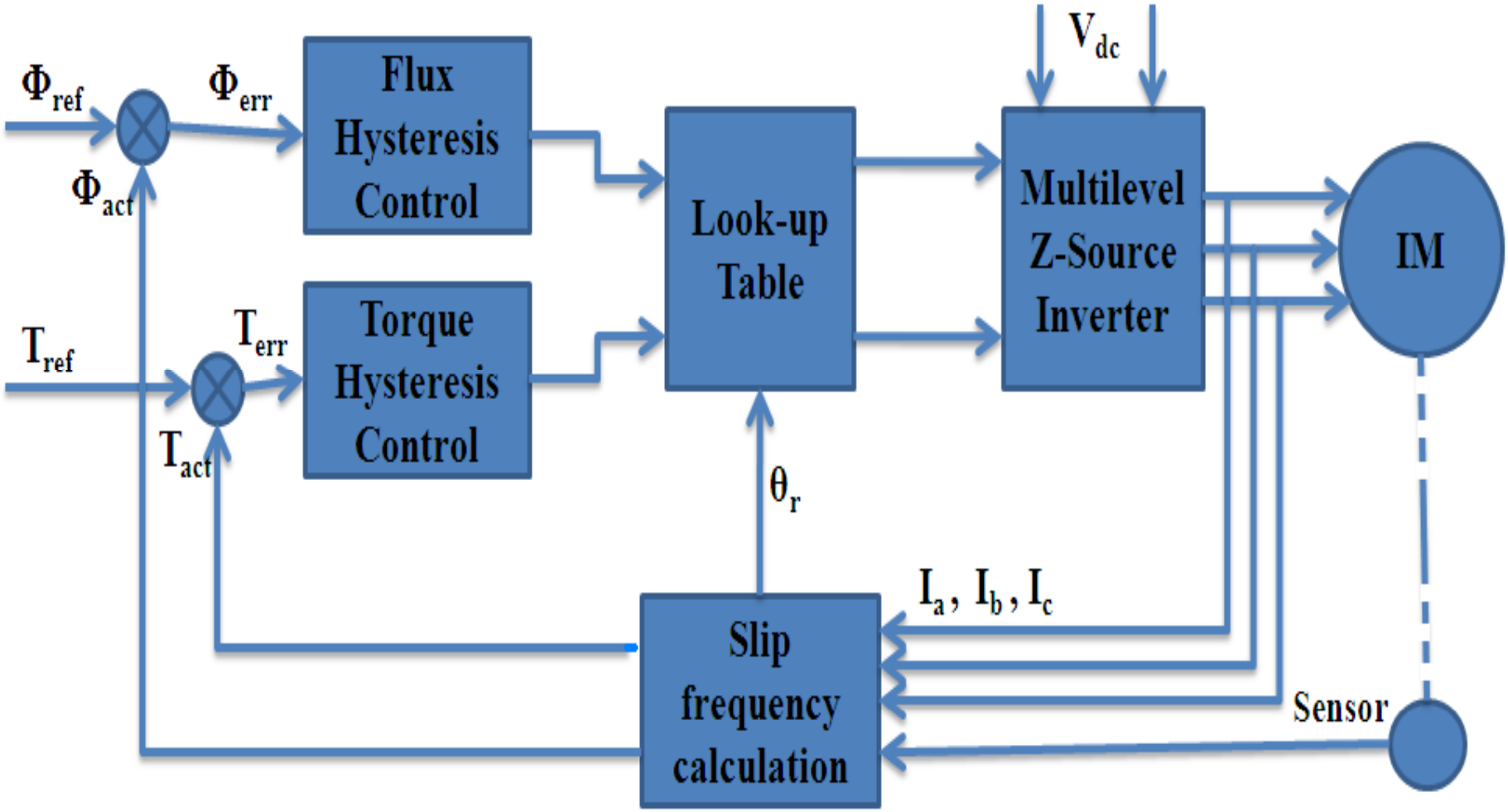


It requires (L-1) number of carriers which are all phase displaced from each other by 180° alternatively

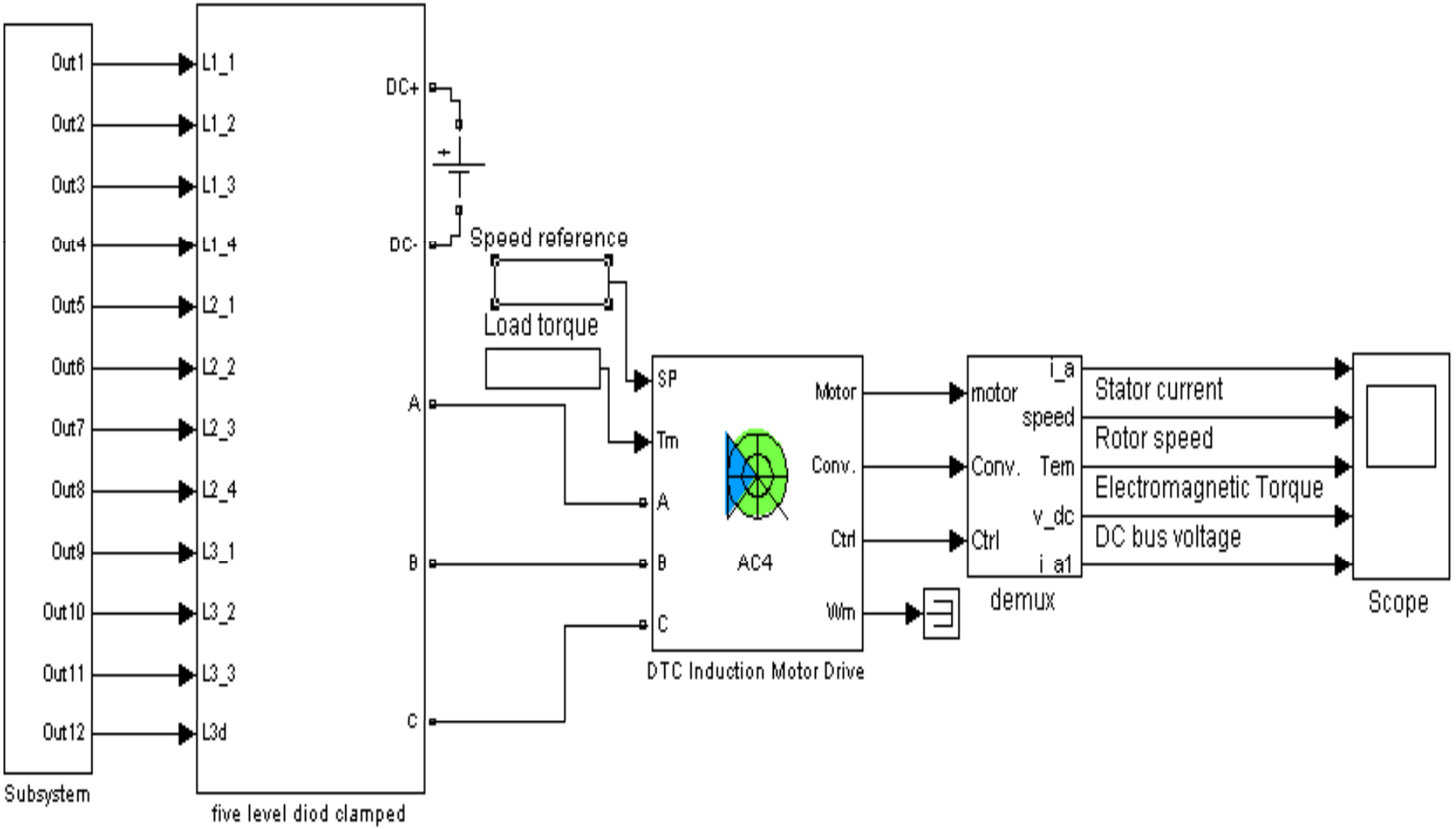
Multicarrier PWM methods

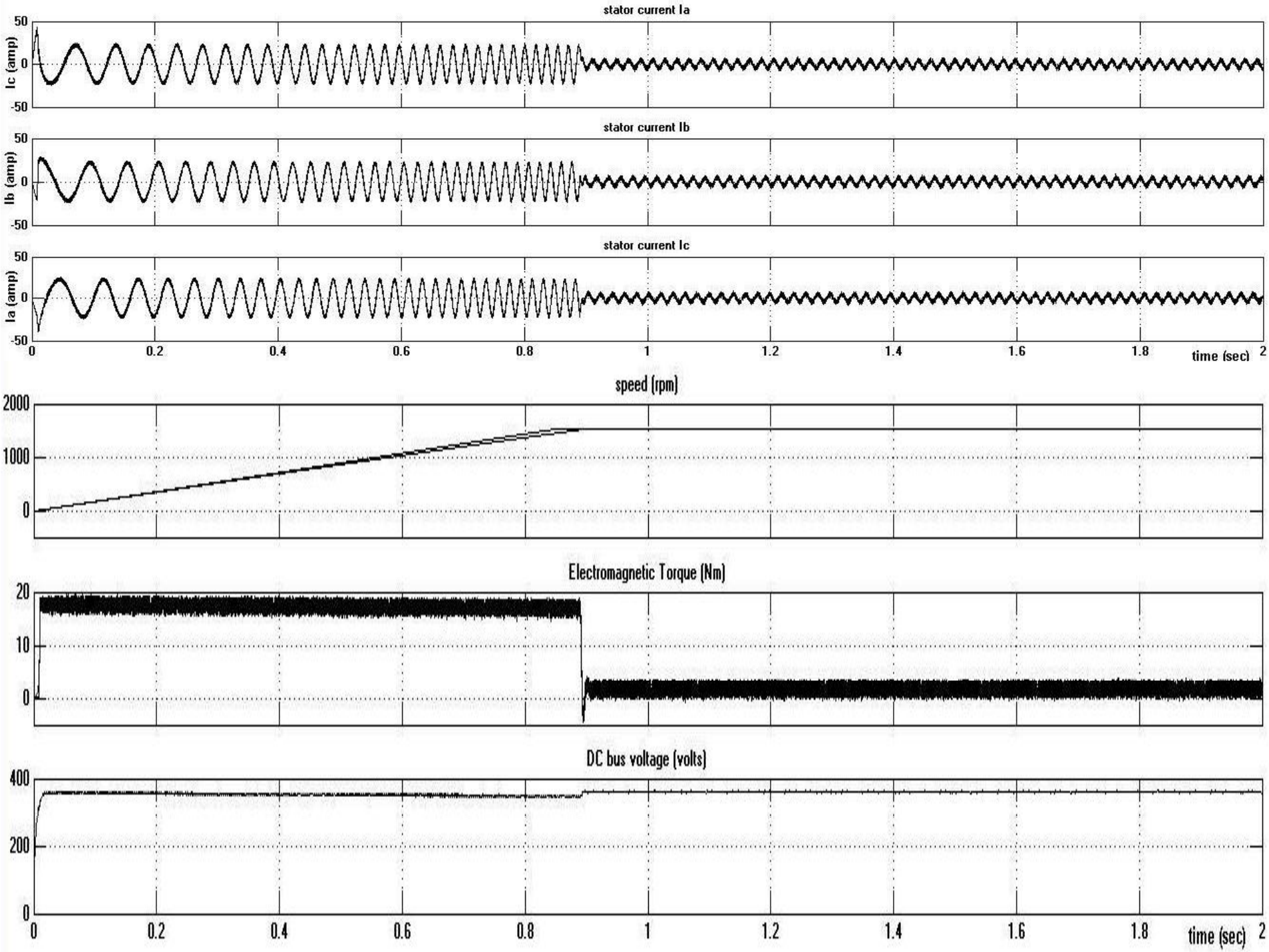


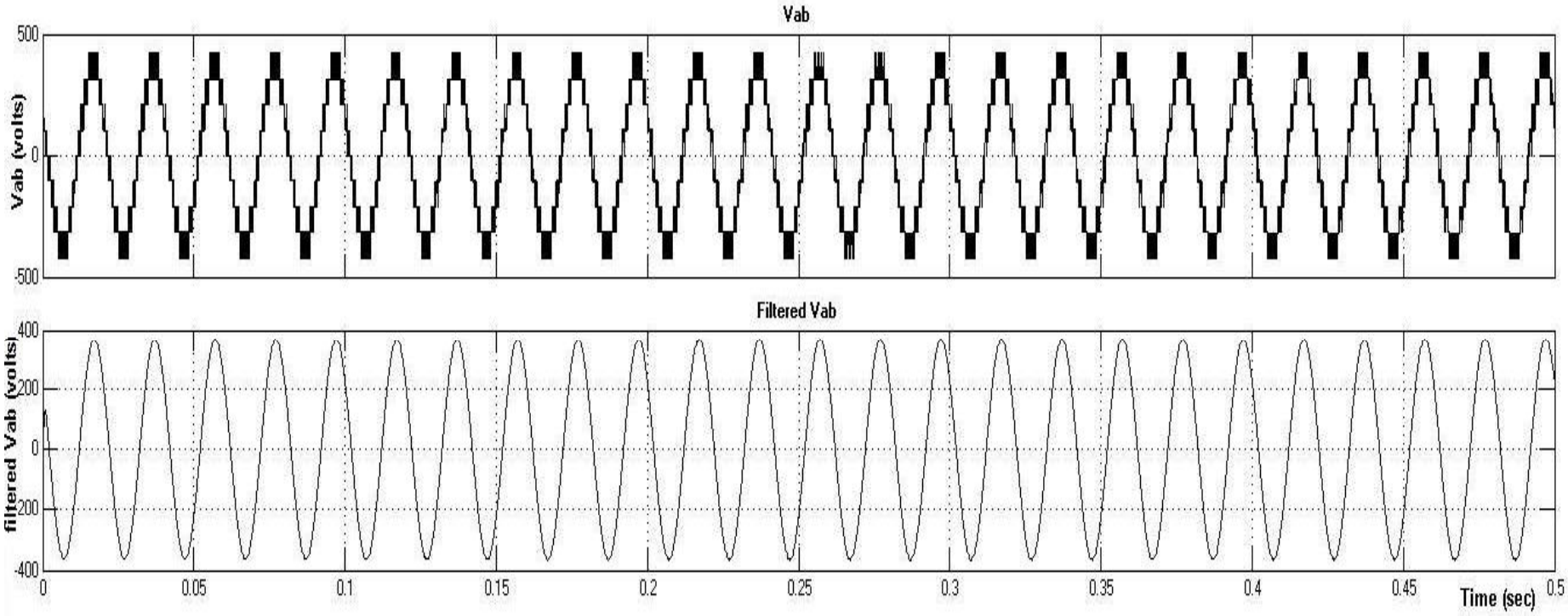
Block diagram of DTCIMD

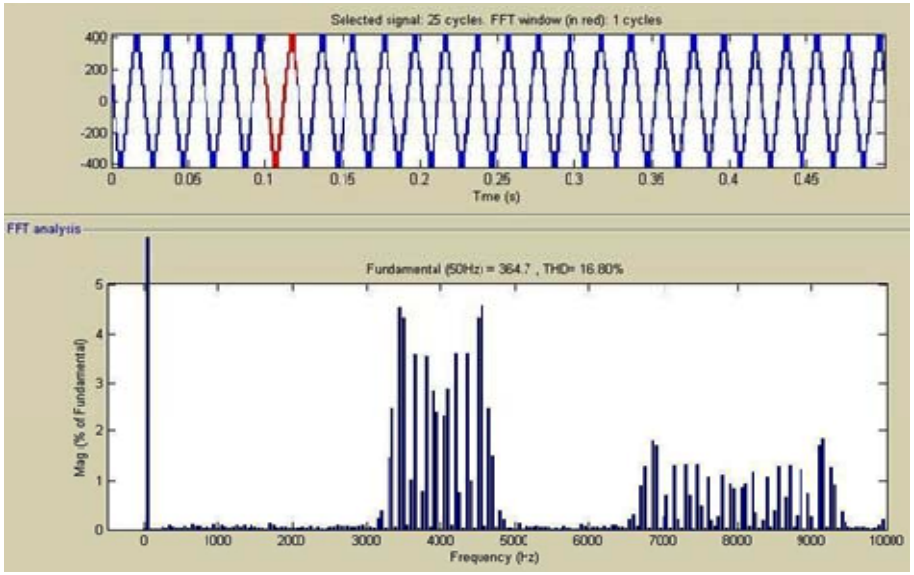


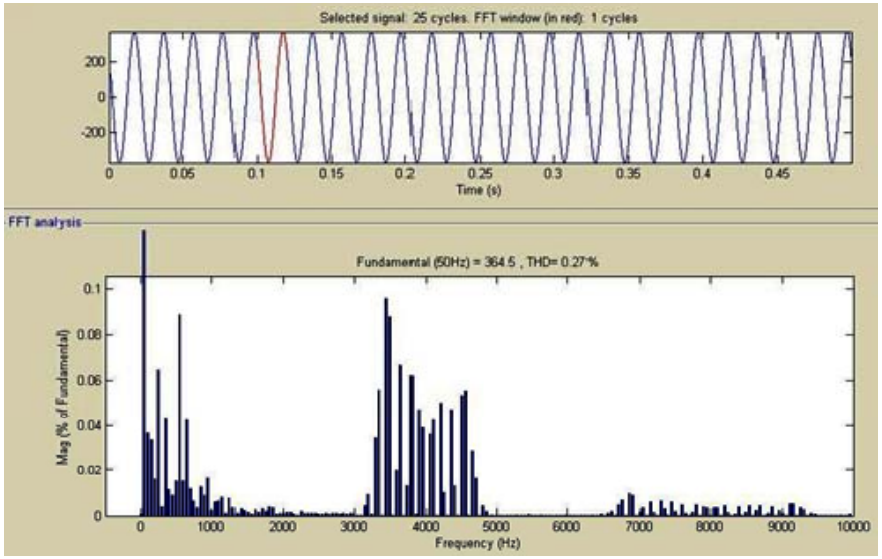
Simulation Circuits & Results



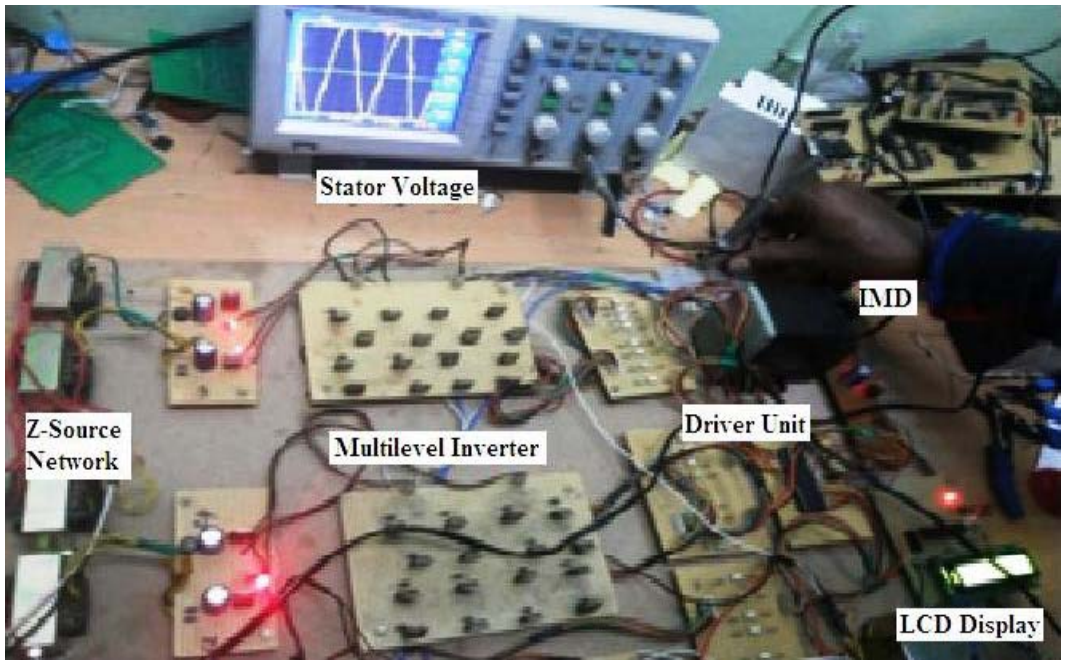

stator current Ia
Ic (amp)
stator current Ib
Ib (amp)
stator current Ic
Ia (amp)
50
0
-50
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
time (sec)
speed (rpm)
2000
1000
0
Electromagnetic Torque (Nm)
20
10
0
DC bus voltage (volts)
400
200
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
time (sec)

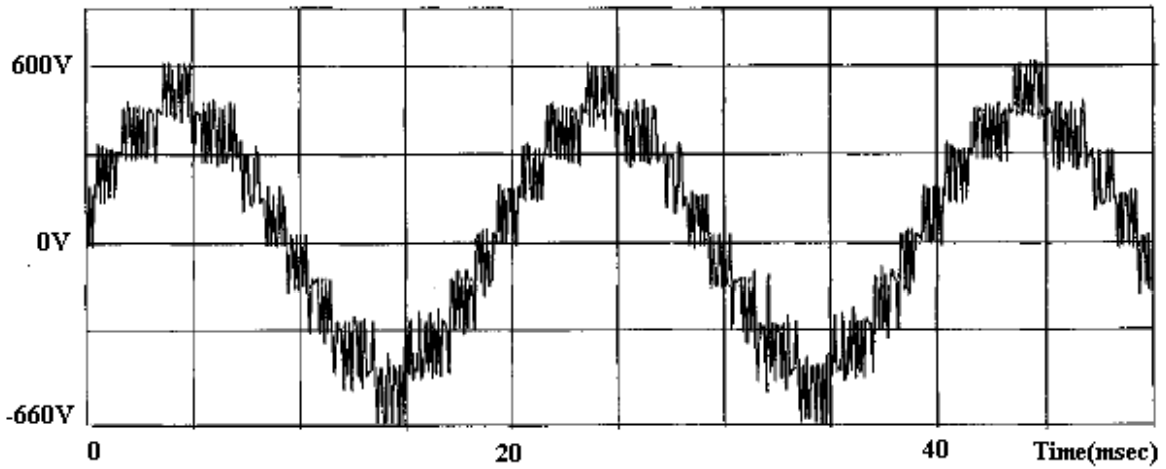

Vab
Vab (volts)
500
0
-500
Filtered Vab
filtered Vab (volts)
400
200
0
-200
-400
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Time (sec)


Selected signal: 25 cycles. FFT window (in red): 1 cycles
Time (s)
FFT analysis
Fundamental (50Hz) = 364.7 , THD= 16.80%
Mag (% of Fundamental)
Frequency (Hz)


Selected signal: 25 cycles. FFT window (in red): 1 cycles
Time (s)
FFT analysis
Fundamental (50Hz) = 364.5 , THD= 0.27%
Mag (% of Fundamental)
Frequency (Hz)

Development of Prototype





Features of Multilevel inverters

- **The harmonics content is lowered with higher switching frequency**
- **EMI reduction**
- **Higher efficiency**
- **Low switching loss**
- **Low frequency harmonics are not presented.**

Applications of Multilevel inverters

- **Reactive power compensation**
- **Adjustable speed drives**

Conclusion

- **The performance analysis of 5-level neutral point clamped z-source inverter fed induction motor drives by simulation as well as building a development of prototype model.**
- **The constraint of prototype model is constructed to make flexibility and adaptability to the practical environment.**
- **Various performance parameters of induction motor like phase currents, stator voltage, speed, torque and DC bus voltage has been investigated using DTC strategy by simulation and prototype model.**
- **The PD, POD, APOD PWM approaches are reviewed for the proposed inverter and acknowledged that POD PWM gives lot better test results over others. From the above results DTC could tremendously reduce current, torque and flux ripples.**

Reference

1. José Rodríguez, Steffen Bernet, BinWu, Jorge O. Pontt, and Samir Kouro. Multilevel voltage-source-converter topologies for industrial medium-voltage drives. IEEE transactions on industrial electronics 2007; 54: 6.
2. Jing Zhao, Xiangning He and Rongxiang Zhao. A novel PWM control method for hybrid clamped multilevel inverters. IEEE transactions on industrial electronics2010; 57: 7.
3. Sara Laali, Karim Abbaszadeh, Hamid Lesani. Development of multi-carrier PWM technique for multilevel inverters. International conference on electrical machines and systems (ICEMS) 2010.
4. Fang Zheng Peng, Alan Joseph, Jin Wang, Miaosen Shen, Lihua Chen, Zhiguo Pan, Eduardo Ortiz-Rivera and Yi Huang. Z-Source inverter for motor drives. IEEE transactions on power electronics2005; 20: 4.
5. Dudi A. Rendusara, Cengelci E, Prasad N Enjeti, Victor R Stefanovic and James W Gray. Analysis of common mode voltage—“neutral shift” in medium voltage PWM adjustable speed drive (MV-ASD) systems. IEEE transactions on power electronics 2000; 15: 6.
6. Yongchang Zhang and Jianguo Zhu. Direct torque control of permanent magnet synchronous motor with reduced torque ripple and commutation frequency. IEEE transactions on power electronics2011; 26: 1

Reference

7. **Khoa D. Hoang, Z. Q. Zhuand Martin P. Foster. Influence and compensation of inverter voltage drop in direct torque-controlled four-switch three-phase pm brushless ac drives. IEEE transactions on power electronics 2011; 26: 8**
8. **Gonzalo Abad, Miguel Ángel Rodríguez and Javier Poza. Two-level VSC based predictive direct torque control of the doubly fed induction machine with reduced torque and flux ripples at low constant switching frequency," IEEE transactions on power electronics 2008; 23: 3.**
9. **Giuseppe S Buja and Marian P Kazmierkowski. Direct torque control of PWM inverter-fed AC motors—a survey. IEEE transactions on industrial electronics 2004; 51:4.**
10. **Nasrudin Abd Rahim, Mohamad Fathi, Mohamad Elias and Wooi Ping Hew. Transistor-clamped H-bridge based cascaded multilevel inverter with new method of capacitor voltage balancing. IEEE transactions on industrial electronics 2013; 60: 8**
11. **Thameur Abdelkrim, El Madjid Berkouk, Karima Benamrane and Tarak Benslimane. Study and control of 5-level PWM rectifier-5-level NPC active power filter cascade using feedback control and redundant vectors. Turk J Elec Eng & Comp Sci 2012; 20: 5.**

Publications

S.NO	TITLE	JOURNAL	ISSUE/ MONTH/ YEAR
1.	**The Comparative Analysis of THD Reduction in Various Multilevel Z-Source Inverters Using Multicarrier PWM Strategies**	**European Journal of Scientific Research (EJSR)**	**Vol 2, Issue 1, February 2013.**
2.	**The Comparative THD Analysis of Neutral Clamped Multilevel Z-Source Inverter Using Novel PWM Control Schemes**	**International Journal of Modern Engineering Research (IJMER)**	**Vol 2, Issue 3, May-June 2012.**

Conferences

S.NO	TITLE	PLACE	DATE
1.	THD Minimization on The Line-line Voltage of Multilevel Inverter	SAINTGITS College of Engineering, Kottayam, Kerala.	6th April 2013
2.	Analysis of Advanced Harmonic Elimination Techniques For Various Neutral Point Clamped Inverter Fed Induction Motor Drive	Sri Ganesh School of Business Management, Selam, Tamil Nadu.	22nd February 2013
3.	The Analysis of Multicarrier PWM Control Techniques for Neutral Clamped Multilevel Z-Source Inverter	Dr.MGR Educational and Research University, Chennal, Tamil Nadu.	12th &13th April 2012
4.	Direct Torque Control of Induction Motor Drive Using Z-Source Inverter	JKKN College of Engg & Tech, Namakkal, Tamil Nadu.	9th &10th March 2012

THANK YOU