International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 06 | June - 2021 ISSN: 2582-3930

Total Harmonic Distortion Analysis of Three Phase Three Level Inverter using Flying Capacitor Topology

Pushpendra kachawatia[1], Ranjan Jhajhariya[2], Vishnu Sharama[3] , Sanjay Sepat[4], Jitendra Singh[5]

[1,2,3,4,5]*Department of Electrical Engineering, Swami Keshawanand Institute of Technology, Management & Gramothan*
Jaipur, Rajasthan, India

***Abstract*— Aim of this paper is to determine the Total Harmonics Distortion (THD) of three phase three level flying capacitor inverter. The modulation technique used is Phase Disposition Sinusoidal Pulse Width Modulation (PD-SPWM). This paper also presents the harmonic analysis of phase voltage and line voltage of three phase three level inverter. In this paper we studied about phase disposition techniques, flying capacitor topology and types of PWM strategies.**

***Keywords*- PWM, PD-SPWM, THD, Inverter, Multilevel Inverter.**

I. INTRODUCTION

1.1 Multilevel Inverters

Multilevel inverters have drawn remarkable interest in power industry due to their merits like higher efficiency, lower common mode voltage, lower voltage stress on power switches, lower dv/dt ratio, no EMI problems & it is best for high voltage and high current applications [1].There are three types of multilevel inverters. They are Diode clamped or Neutral clamped Flying capacitor or Capacitor clamped. Cascaded H- bridge multilevel inverters [2] [3]. During the 1980s the event of the Multilevel Converters didn't move much forward. Only after ten years, at the turn of the last decade, finally appeared articles about new applications, e.g. nuclear fusion, and new control methods. The next turning point came at the start of the 1990s when Meynard and Foch (1992) presented the flying capacitor converter as a multilevel chopper and a multilevel inverter.

The FCMLI is taken into the account for THD analysis in during this paper because it's easier to extend number of levels in this inverter than the diode clamped multilevel inverters. The advantage of this inverter is that it can control both real and reactive power flow.

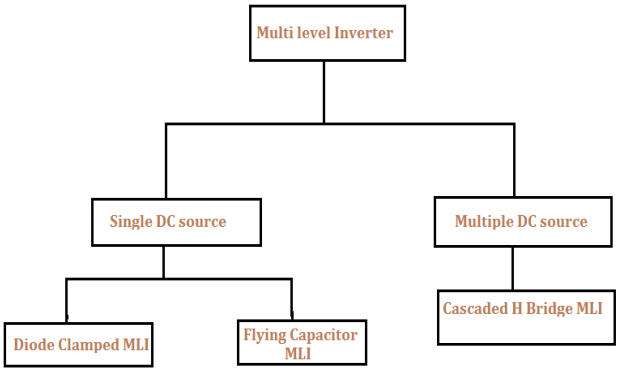

Figure-1.1.1: Classification of Multilevel Inverter

1.2 Multilevel Inverter PWM Strategies

PWM control strategies are evolution to scale back the entire Harmonic Distortion [4].PWM strategies utilized in conventional inverters are often modified to use in MLI. The advent of multilevel inverter PWM modulation methodologies are often classified consistent with switching frequency as shown in figure 1.2.1

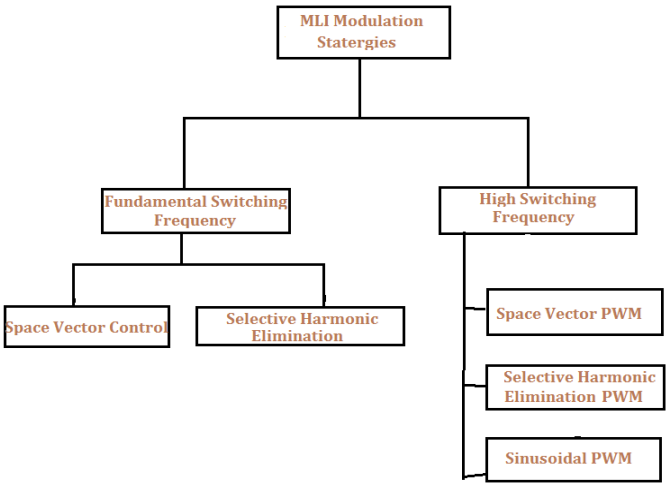

Fig-1.2.1: Classification of Multilevel Inverter PWM Strategies

There are several Multi carrier based High frequency techniques such as

(i) Phase disposition PWM (PDPWM)
(ii) Phase Opposition Disposition PWM (PODPWM)
(iii) Alternate Phase Opposition Disposition PWM

(APODPWM)
(iv) Phase Shift PWM (PSPWM)
(v) Alternate Phase Shift PWM (APSPWM)
(vi) Carrier Over Lap PWM (COPWM)
(vii) Variable Frequency PWM (VFPWM)
(viii) Alternate Variable Frequency PWM (AVFPWM)

In multilevel Inverters modulation index is defined as follows

$$M.I = Am/(m-1)Ac$$

In this Paper, PD SPWM technique is used for triggering switches of three phase three level flying capacitor inverter[5]-[10].

Phase Disposition Method

In the phase disposition (PD) method, all carriers are selected with an equivalent phase. With regard to the related research works during this field, this method leads to low THD at higher modulation indices than the another schemes[11]-[14].

Phase Opposition Disposition

In this method, there's no harmonic at the carrier frequency and its multiples and therefore the diffusion of harmonics occurs therein region. The simulation of the POD technique was administered in MATLAB/Simulink environment[15]-[18].

Alternate Phase Opposition Disposition

In this method, each carrier signal is shifted by 180 degrees in phase from the another signal. This method gives almost an equivalent results because the POD method but the sole difference is that the triple-n harmonics are eliminated due to the cancellation of line voltages. The simulation of the APOD technique was administered in MATLAB/Simulink environment[19] [20].

Multilevel Carrier PWM Technique

The conventional multilevel carrier PWM is capable of comparing several carrier signals with a one reference signal per phase. For a p-level inverter, p-1 carriers with an equivalent frequency and amplitude are used. The authors have explained a completely unique PWM technique during which the carrier signals are disposed alternatively. The waveforms for both conventional and modified multilevel PWM signals [21]-[23] .

Phase Shift Method

The phase-shifted PWM is that the standard modulation technique for cascaded multilevel inverters due to the fact that it can yield an honest end in reducing output harmonics and maintaining a power distribution balance among power cells[24].

2. Flying Capacitor Multilevel Inverter

The three phase three level flying capacitor inverter is shown in Fig.2.1. This inverter is named so because the capacitor's floats with reference to earth potential. Flying capacitor Multi level inverter is additionally referred to as Capacitor clamped multilevel inverter. For m level flying capacitor inverter consists of 2(m-1) switches, (m-1) main capacitors and (m-1)*(m-2)/2 auxiliary capacitors are required in each phase leg. Thus a three level flying capacitor inverter consists of four switches, two main capacitors & one auxiliary capacitor in each leg [25].

FCMI involves within the usage of additional capacitor clamped to the facility switches phase rail to supply the DC voltage level. This structure allows for the inverter to provide high capabilities especially during the power outages due to the redundancy in switching states provided by the clamping capacitor.

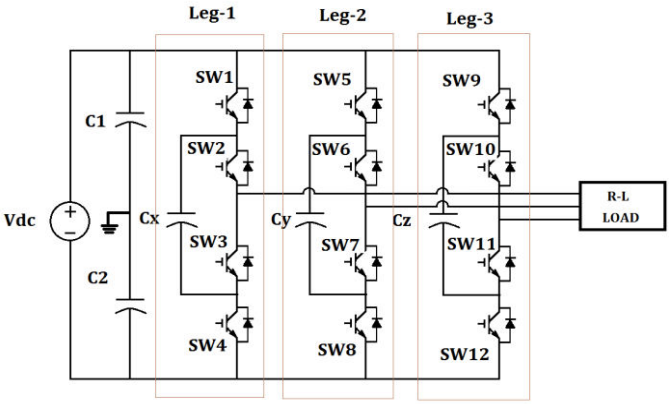

Fig-2.1: Three Phase Three Level Flying Capacitor Inverter

The possible switching states are four in 3 level FCMLI. When the switches SW1, SW2 are ON and SW3, SW4 are OFF the output voltage is positive. When switches SW3, SW4 are ON and SW1, SW2 are OFF the output voltage is negative. Zero level can be obtained in two ways that is either SW1, SW3 are ON or SW2, SW4 are ON [26].

Table -2.1: Switching states and output voltage of leg1of three level flying capacitor inverter

Switching state	S1	S2	S3	S4	Vout
1	0	0	1	1	-Vdc/2
2	1	0	1	0	0
3	0	1	0	1	0
4	1	1	0	0	+Vdc/2

3. PD-SPWM CONTROL TECHNIQUE

3.1. Phase disposition sinusoidal pulse width modulation

In SPWM technique, sinusoidal reference wave is compared with triangular carrier waveform to get pulses to switches of inverter. This traditional SPWM technique is employed to

multilevel inverter by using multiple carriers. For m level inverter (m-1) carriers are required. Phase disposition SPWM has carriers in same phase above and below zero reference line. All the carrier signals are of same frequency and same amplitude in PD-SPWM. It's most generally used method because it provides low harmonic distortion in load voltage and current [27] [28].

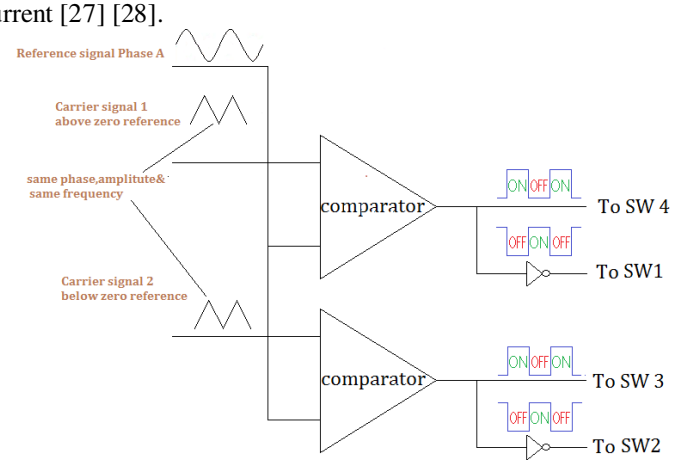

Fig-3.1.1: Phase disposition sinusoidal PWM

4. SIMULATION AND RESULTS OF PD-SPWM CONTROLLED THREE PHASE THREE LEVEL FLYING CAPACITOR INVERTER

A Three phase three level flying capacitor inverter using PD-SPWM Controlled technique is simulated in MATLAB Simulink.

MATLAB Simulation parameters are

1. Carrier Frequency=400 Hz
2. System Frequency=50 Hz
3. Load resistance(R) =10 Ohm
4. Input D.C voltage=100 V

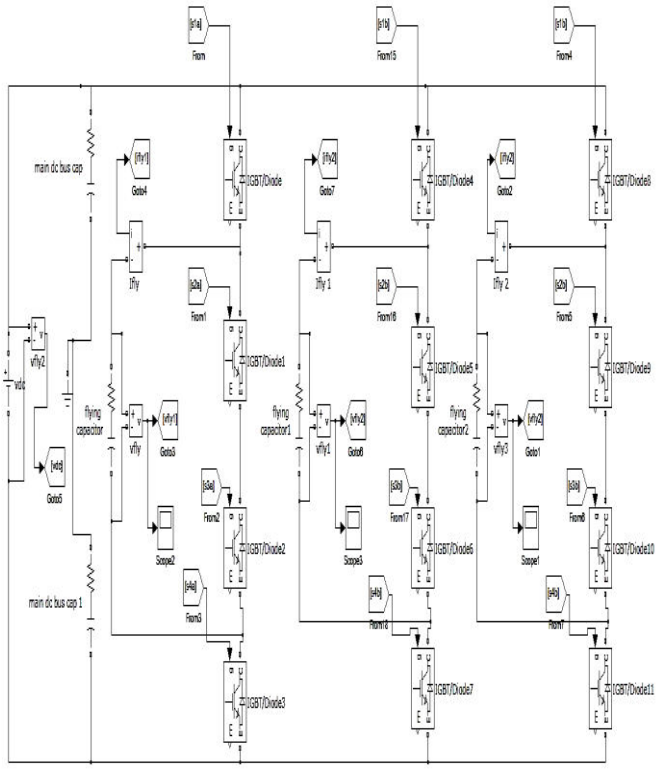

Fig-4.1: Simulink model for PWM based Three phase three level flying capacitor inverter

The flying-capacitor inverter can theoretically be constructed to give an unlimited number of voltage levels, but practical designs are usually limited to six levels. The number of possible voltage levels is related to the number of power switching devices connected in series in each inverter leg.

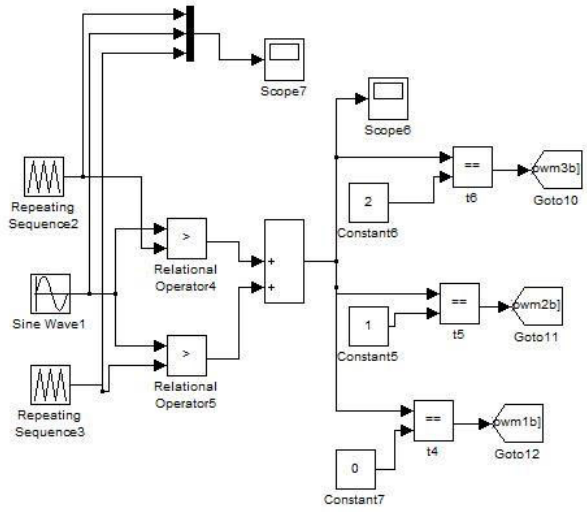

Fig-4.2: Simulink model for PD-SPWM switching signal generation

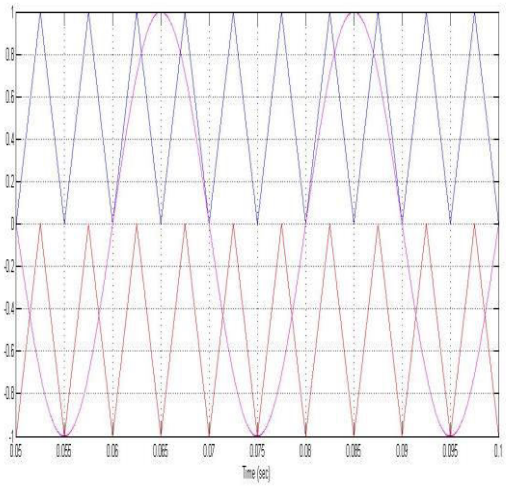

Fig-4.3: Carrier signals and reference signals for PD-SPWM

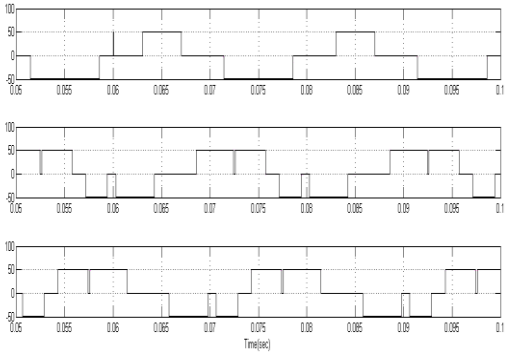

Fig-4.4: Phase voltage waveforms of PD-SPWM 3-phase 3-level flying capacitor inverter

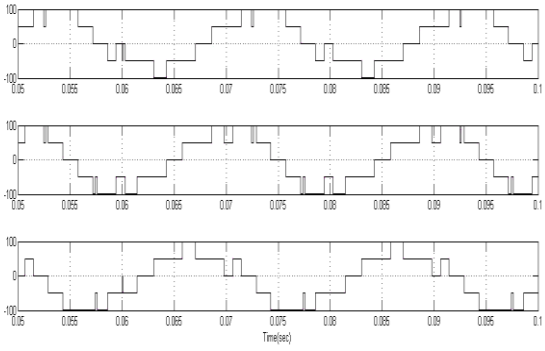

fig- 4.5: Line voltage of PD-SPWM 3-phase 3-level flying capacitor inverter

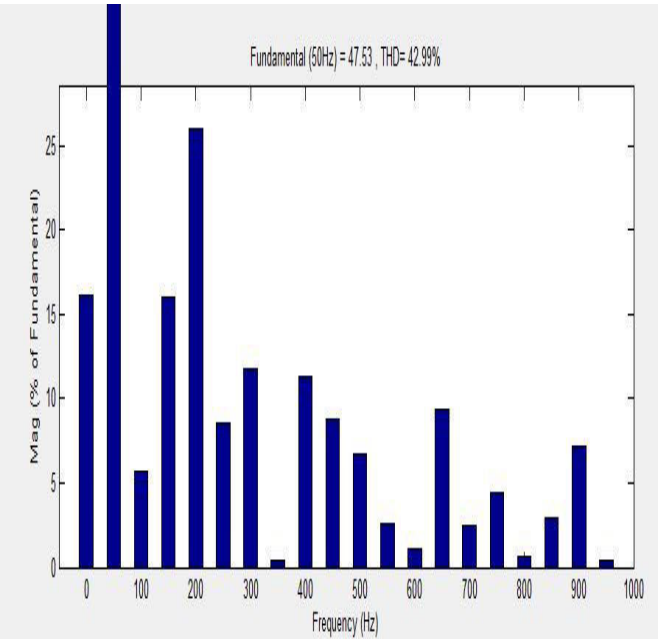

Fig-4.6: THD of phase voltage of PD-SPWM 3-phase 3-level flying capacitor inverter

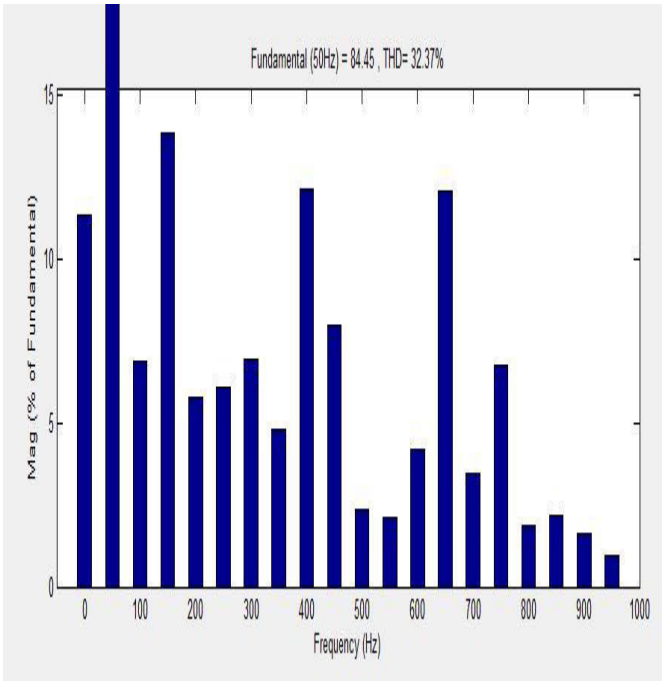

Fig-4.7: THD of line voltage of PD-SPWM 3-phase 3-level flying capacitor inverter

CONCLUSIONS

In this three phase three level flying capacitor inverter is implemented by using the PD-SPWM technique. In this analysis of THD of phase voltage and line voltage is done. And compare to other strategies the PD-SPWM technique is much better. A MLI has several advantages over conventional two

level converter that uses high switching frequency pulse width modulation (PWM). The attractive features are :

1. **Input current**: Multilevel inverter can draw input current with low distortion.
2. **Switching frequency**: Multilevel inverter can operate at both fundamental switching frequency PWM. It should be noted that lower switching frequency usually means lower switching and higher efficiency.
3. **Common-mode (CM) voltage:** Multilevel converters produce smaller CM voltage; therefore, the stress in the bearings of a motor connected to a multilevel motor drive can be decreased. Furthermore, CM voltage can be eliminated by using advanced modulation strategies.
4. **Staircase waveform quality:** Multilevel converters not only can generate the output voltages with very less distortion, but also can decrease the dv/dt stress; therefore electromagnetic compatibility (EMC) problems can be bring down.

REFERENCES

[1] S. M. Metev and V. P. Veiko, *Laser Assisted Microtechnology*, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2] J. Breckling, Ed., *The Analysis of Directional Time Series: Applications to Wind Speed and Direction*, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.

[3] S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, "A novel ultrathin elevated channel low-temperature poly-Si TFT," *IEEE Electron Device Lett.*, vol. 20, pp. 569–571, Nov. 1999.

[4] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in *Proc. ECOC'00*, 2000, paper 11.3.4, p. 109.

[5] R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, "High-speed digital-to-RF converter," U.S. Patent 5 668 842, Sept. 16, 1997.

[6] (2002) The IEEE website. [Online]. Available: http://www.ieee.org/

[7] M. Shell. (2002) IEEEtran homepage on CTAN. [Online]. Available: http://www.ctan.org/tex-archive/macros/latex/contrib/supported/IEEEtran/

[8] *FLEXChip Signal Processor (MC68175/D)*, Motorola, 1996.

[9] "PDCA12-70 data sheet," Opto Speed SA, Mezzovico, Switzerland.

[10] A. Karnik, "Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP," M. Eng. thesis, Indian Institute of Science, Bangalore, India, Jan. 1999.

[11] J. Padhye, V. Firoiu, and D. Towsley, "A stochastic model of TCP Reno congestion avoidance and control," Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.

[12] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.

[13] Jitendra Sir: Sunil Kumar Goyal, Jitendra Singh, Amit Saraswat, Neeraj Kanwar, Manish Shrivastava and O. P. Mahela "Economic Load Dispatch with Emission and Line Constraints using Biogeography Based Optimization Technique", 2020 International Conference on Intelligent Engineering and Management (ICIEM), ISBN: 978-1-7281-4097-1, pp. 471- 476, Aug. 2020.

[14] Muhammad H. Rashid-"Power Electronics-Circuits, Devices and Applications" Pearson Education Incorporated, 2005.

[15] Tolbert. L. M and Pend. F. Z -"Multilevel Converter as Utility Interface for Renewable Energy Systems", IEEE Power Engineering Society Meeting, Vol. 2, pp. 1271- 1274, 2000.

[16] Jitendra Sir: Sunil Kumar Goyal, Jitendra Singh, Amit Saraswat, Neeraj Kanwar, Manish Shrivastava and O. P. Mahela "A case study on combined economic emission and load dispatch using biogeography based optimization technique", International Journal of Forensic Engineering, Vol. 4, No. 4, pp. 261- 277, 2020.

[17] BK Bose-"Power electronics-An emerging technology" IEEE Transactions on Industrial Electronics, vol.36, no.3, pp. 403–12, Aug 1989.

[18] Mohd Esa and Mohd Abdul Muqeem Nawaz, "THD analysis of SPWM & THPWM Controlled Three phase Voltage Source Inverter", International Research Journal of Engineering and Technology (IRJET), vol. 04, no. 10, pp. 391-398, 2017.

[19] Mohan N, Undeland TM, Robbins WP. Power electronics-converters, and design. New York: John Wiley & Sons Inc.; 1995.

[20] L., Zhang, S.J., Watkins, w., Shepherd, Analysis and Control of A Multi-level Flying Capacitor Inverter, Power Electronics Congress 2002, Technical Proceedings, CIEP 2002, VIII IEEE In-ternational, 2002, pp. 66-71

[21] Peng FZ, McKeever JW, Adams DJ. Cascade multilevel in-verters for utility applications. In: Proceedings of 23rd interna-tional conference on industrial elect. control and inst, New Orle-ans (USA); 1997.

[22] Jitendra Sir: itendra Singh and Sunil Kumar Goyal, "Transmission Constrained Economic Load Dispatch using Biogeography Based Optimization", 2014 IEEE International Conference on Computational Intelligence and Computing Research, ISBN: 978-1-4799-3975-6, pp. 1-5, Sept. 2015.

[23] Manjrekar MD, Lipo TA. A hybrid multilevel inverter topol-ogy for drive applications. In: Proceedings of IEEE applied power elec conference; 1998.

[24] Jinghua Z, Zhengxi L. Research on hybrid modulation strate-gies based ongeneral hybrid topology of multilevel inverter. In: Proceedings of int symppower elect, elec drives, motion, Ischia

[25] Kouro S, Rebolledo J, Rodriguez J. Reduced switching-frequency-modulation algorithm for high-power multilevel in-verters. IEEE Trans Ind Electron 2007;54:2894–901.

[26] Ismail B, Taib S, Saad RM, Isa M, Hadzer CM. Development of a single phase SPWM microcontroller-based inverter. In:Proceedings of 1st international power and energy conference PECon 2006, Putraja (Malaysia); 2006.

[27] Jitendra Sir: Jitendra Singh and Sunil Kumar Goyal, "Optimization of Economic Load Dispatch Problems using Biogeography Based Optimization Technique", 2015 International Conference on Energy Economics and Environment (ICEEE), ISBN: 978-1- 4673-7492-7, pp. 1-5, 2015.

[28] Loh PC, Bode GH, Holmes DG, Lipo TA. A time-based hyste-resis current regulation strategy for single-phase multilevel in-verters. IEEE Trans Ind. Appl 2003;39:883–92.