International Journal of Electrical Engineering & Emerging Technology, Vol. 02, No. 01, JUNE 2019, pp 17-22

Power Quality Analysis of Solar Photovoltaic fed cascaded H-bridge five level inverter

Khalid Hussain Shah [a*], Asif Ali Solangi [b], Rizwan Ali Siyal [c]
[a] Hyderabad Collage of Science and Technology, Hyderabad, Pakistan
[b] Mehran University of Engineering and Technology SZAB campus Khairpur mir's, Pakistan
[c] Institute of Information and Communication Technology, Mehran University of Engineering & Technology, Jamshoro Pakistan

Corresponding author e-mail: khalid.student@yahoo.com

[Received on: 10-04-2019 Accepted on: 24-05-2019 Published on: 05-06-2019]

***Abstract*. In recent advancement in semiconductor technology make it possible to generate electrical energy from the photovoltaic systems at high power level and integrate these photovoltaic systems to utility gird. The major components which constitute the photovoltaic systems are photovoltaic array, power electronic converter and control systems for switching of power electronic converters. The inverter which is one of fundamental component conventionally are of two level inverter or square wave inverters but these inverter has poor THD, voltage stresses are high on semiconductor devices which make its mismatch with high power and high voltage applications. Multilevel inverter which provides better THD and lesser voltage stresses in this scenario. In this research paper a photovoltaic system is proposed for THD analysis of cascaded H-bridge five level inverter with multicarrier based PWM modulation technique. P&O algorithm is utilized in photovoltaic system for maximum power point tracking. Output voltage THD is analyzed in the linear region of modulation index for phase disposition PWM, phase opposition disposition PWM, alternate phase opposition disposition PWM and phase shifted PWM modulation technique. A comparative analysis is done for all the multicarrier modulation technique.**

***Index Terms*—Cascaded H-Bridge, Maximum Power Point Tracking, Photovoltaic System, Perturb & Observe Algorithm, Pulse Width Modulation, Total Harmonic Distortion**

I. INTRODUCTION

Generation of electrical energy from alternate energy resource is one of the most popular topic in the research consideration. But among these alternate energy resource wind energy and solar energy take the considerable part in the research work [01]. Solar photovoltaic (PV) systems are the fastest growing energy conversion alternate energy resource and by time grid connected photovoltaic systems also increases because of the growth in technology make it easy to integrate it into grid. In the recent years solar Photovoltaic systems interconnection with the grid is increased exponentially [02]. The electrical energy generated from the solar photovoltaic system is in dc form this can be utilized for small dc load but for grid integration this is converted into ac form. The conversion of dc form to ac form is the job of inverter. Multilevel inverter found suitable place in high power and high voltage applications because multilevel inverter provides low switching stress on semiconductor device and for the same switching frequency reduce output voltage harmonics. According to configuration these multilevel inverter broadly has three topologies. (a) Diode clamped multilevel inverter (b) Capacitor clamped multilevel inverter (c) Cascaded H-bridge (CHB) multilevel inverter. Due to modular nature and independent separate dc source for each bridge cascaded H-bridge multilevel inverter are suitable for renewable energy sources in grid integration. [03][04][05] The switching signal for these multilevel inverter are generated by implementing the modulation technique. The famous modulation technique these multilevel inverters is multicarrier based PWM modulation technique. In carrier based PWM modulation technique a single reference wave (sinusoidal wave) is compared with many carrier waves to generate switching single for the multilevel inverter switches. [06]

Output power of the photovoltaic systems are not constant due the varying nature of solar radiation and temperature. In this regard generally a maximum power point tracking is employed in combination with dc dc converter. In literature there are many maximum power point tracking algorithms but for photovoltaic systems Perturb & Observe (P&O) algorithm and Incremental Conductance (IC) algorithms are utilized popularly. [07] [08] [09]

II. PHOTOVOLTAIC SYSTEM

Photovoltaic systems can convert solar energy directly into electrical energy. Popularly there are two technologies which are utilized to fed electrical energy for end user load.

1. Grid connected PV system
2. Standalone PV system

For grid connected PV System generated electrical power directly integrated with power system grid. Whereas in standalone PV System the generated electrical power is individually and directly utilized by end user load. Standalone PV System mostly used in remote areas and also for rural electrification as well as for home application at small scale. [10] [11] [12]

A. COMPONENTS OF PHOTOVOLTAIC SYSTEM

The Photovoltaic system can be constituted by different components but components discussed below structure a complete PV System. [13] [14]

1. Photovoltaic (PV) array
2. Power electronics converters
3. Switching technique for inverter
4. Maximum power point tracking

B. MULTILEVEL INVERTER TOPOLOGIES

The multilevel inverters for dc to ac electrical power conversion has various topologies. The power electronic switches are structured in different ways to form particular topology. The popular multilevel inverter topologies which provides the basic concept of step waveform generation are given below. [15] [16] [17] [18]

1. Diode clamped topology
2. Capacitor clamped topology
3. Cascaded H bridge topology

C. MULTICARREIR PWM SWITCHING TECHNIQUE FOR MULTILEVEL INVERTER

The application of PWM switching technique for multilevel inverter has same concept as it has for conventional inverter. The PWM techniques applied to multilevel inverters are known as multicarrier PWM switching technique. These techniques uses the single reference wave in combination with more than one carrier i-e carriers are selected in accordance with multilevel inverter level requirement.
For the particular voltage level the carrier required are:

Cn = m-1
Cn number of carrier
m number of levels

These techniques further classified according to the method by which these carrier compared with the reference wave or sinusoidal wave.

1. Phase shifted pulse width modulation (PSPWM)
2. Phase disposition pulse width modulation (PDPWM)
3. Phase opposition disposition pulse width modulation (PODPWM)
4. Alternate phase opposition disposition pulse width Modulation (APODPWM)

Modulation index for multicarrier switching technique is defined in

M.I = Am / (m-1) Ac
Am= modulating wave amplitude
Ac= carrier wave amplitude. [19] [20] [21] [22] [23]

III. PROPOSED PHOTOVOLATAIC SYSTEM

Stand-alone Photovoltaic systems is proposed for the THD analysis of cascaded H-bridge five level inverter output voltage. The main components which constitute the system are PV array along with MPPT, dc dc boost converter and cascaded H-bridge five level inverter. P&O MPPT algorithm is implemented in combination of dc dc boost converter and multicarrier based PWM modulation technique is used for the switching of cascaded H-bridge five level inverter. Separate MPPT along with dc-dc converter are implemented for individual bridge as shown in the Fig. 1.

For the simulation of proposed photovoltaic system following parameters are used. For the proposed simulation model the main design parameters of PV system are shown in Table I, II, III and IV respectively for PV array, P&O Algorithm, DC-DC boost converter and CHB five level inverter.

TABLE I: PV module and array

Module	
Module	1soltech isth-215-p
P_{mpp}	213.15 W
I_{mpp}	7.35 A
V_{mpp}	29 V
Array	
Series strings	3
Parallel strings	8
P_{mpp}	5.112 kw
I_{mpp}	58 A
V_{mpp}	87 V
Temperature	Irradiance
25 °C	1000 w/m^2

TABLE II: P&O Algorithm

Step size	0.005
Carrier frequency	20 kHz

TABLE III: DC-DC boost converter

Inductor	125 µH
Input capacitor	500 µF
Output capacitor	7500 µF

TABLE IV: CHB five level inverter

Output resistance	8 Ω
Reference wave frequency	50 Hz
Carrier wave frequency	10 kHz

A. P & O Algorithm implementation and performance

The P&O algorithm basically generates perturbation in duty cycle of boost converter to increase or decrease PV array voltage in accordance to increase or decrease PV array power output. Direct duty cycle perturbation for P&O Algorithm is implemented for the proposed simulation model. The MATLAB/SIMULINK implementation for P&O algorithm with direct perturbation in duty cycle of boost converter is shown in Fig. 2. The parameters for Simulation are shown in table II. The specialized technology tool from MATLAB/SIMULINK is used to create PV array from 8 Parallel and 3 series of 1soltech isth-215-p solar modules. PV Curve for the proposed PV array is shown in Fig.3 this curve gives max power for array which is 5112 w at 25 degree and 1000 irradiance.

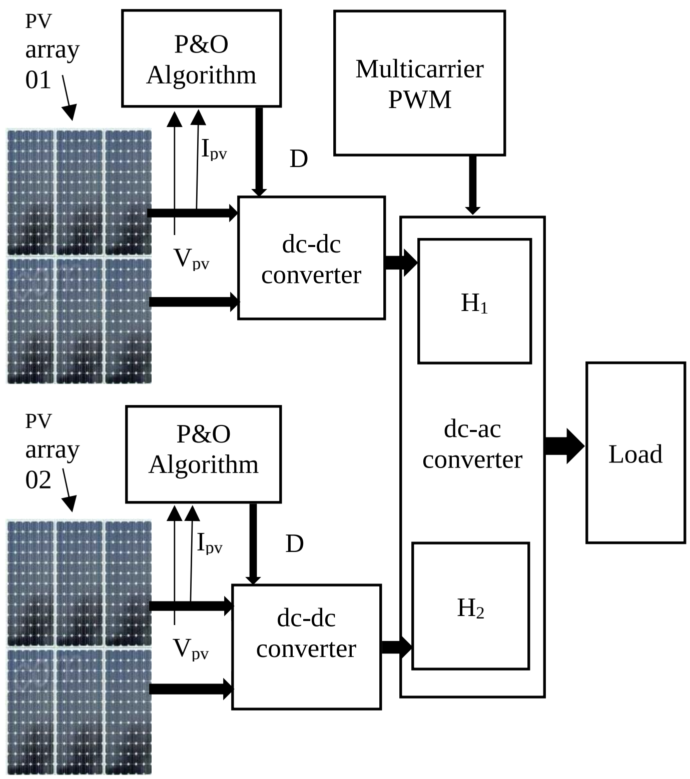
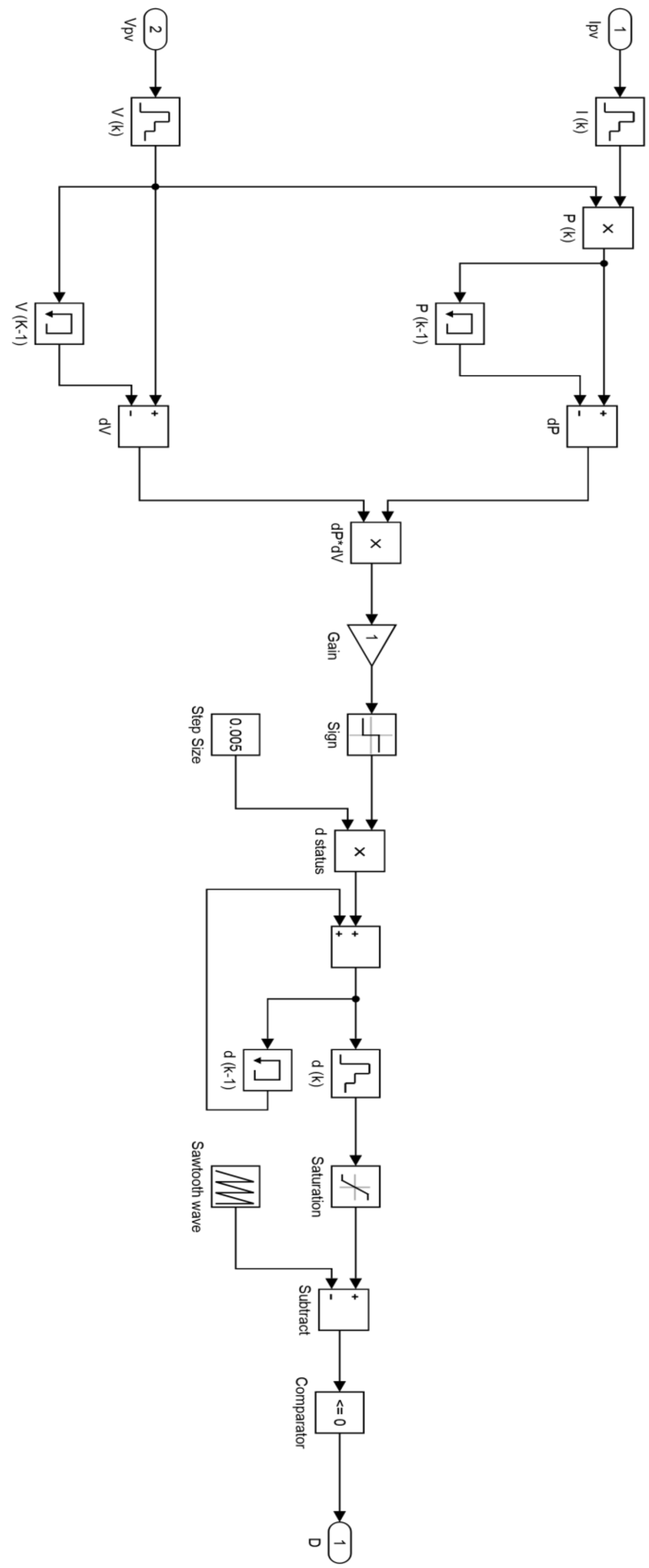


Fig. 1. Block diagram of Photovoltaic system

Firstly performance MPPT for single PV array with boost converter is observed individually which is shown in Fig.4 gives good results of power convergence. Cascaded H-bridge multilevel inverter requires individual supply for each H-bridge. The PV system constructed from CHB five level inverter requires two PV arrays that is one for each single H-bridge and MPPT is independently implemented on both PV arrays as shown in Fig. 1 which shows the proposed PV system. The performance MPPT for both PV arrays i.e. PV array01 and PV array02 is shown in Fig.5 and Fig.6.

The performance of P&O Algorithm MPPT for the proposed PV array is observed individually as shown in the Fig.4. The convergence of the power is accurate but slow because of the step size of the algorithm. Then the performance of the MPPT P&O Algorithm observed for the both PV arrays i-e PV array01 and PV array02 when complete system is analyzed Each MPPT algorithm gives the power convergence as before in individual case but here it is seen that there are Oscillations when the algorithm reaches near maximum power point.



.

Fig. 2. P&O algorithm simulation model (Conventional)

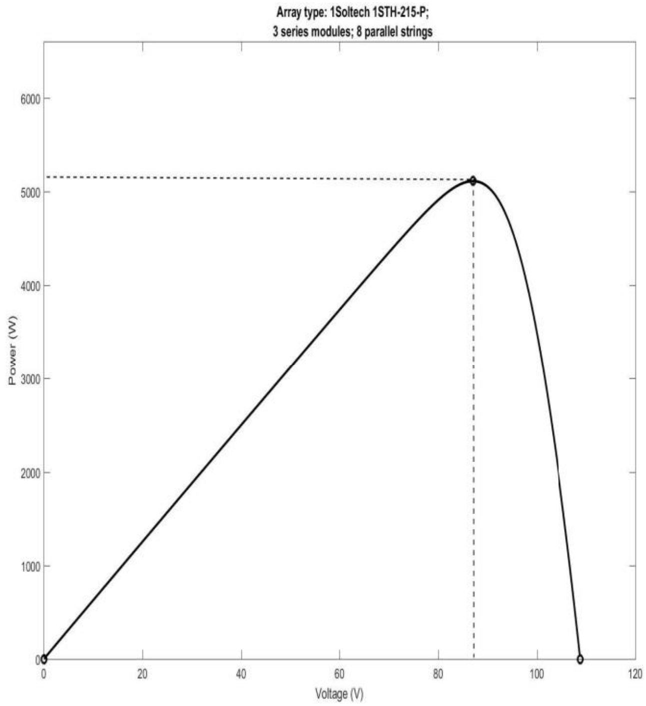


Fig. 3. PV CURVE

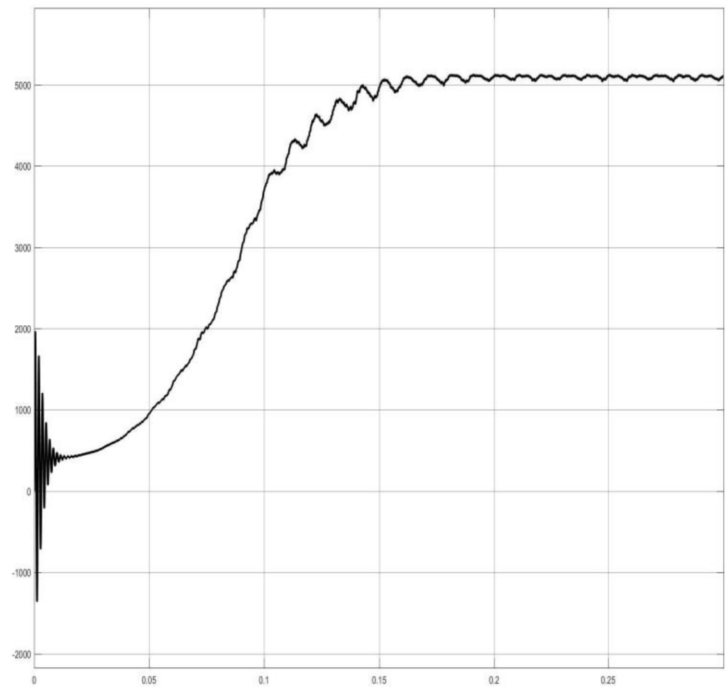


Fig. 5. Performance of MPPT P&O Algorithm for PV Array 01

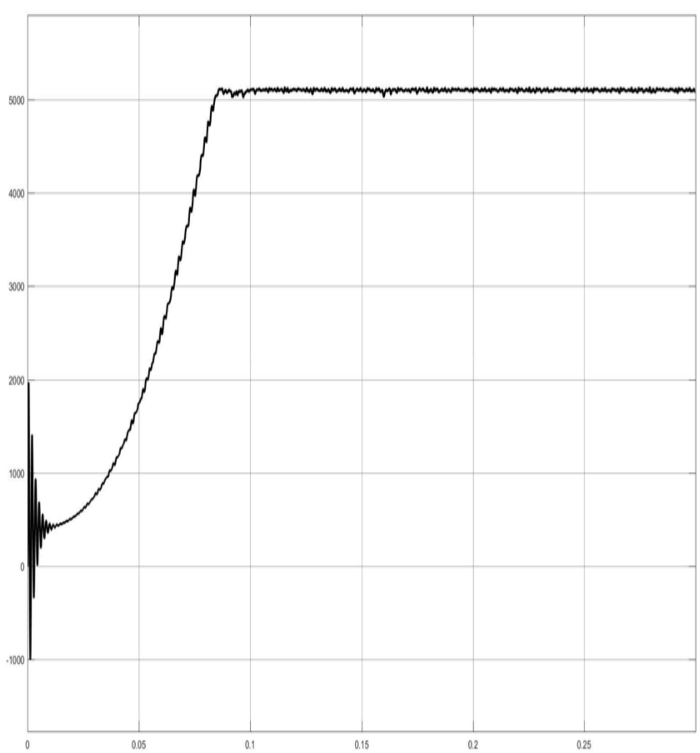


Fig. 4. Performance of MPPT P&O Algorithm

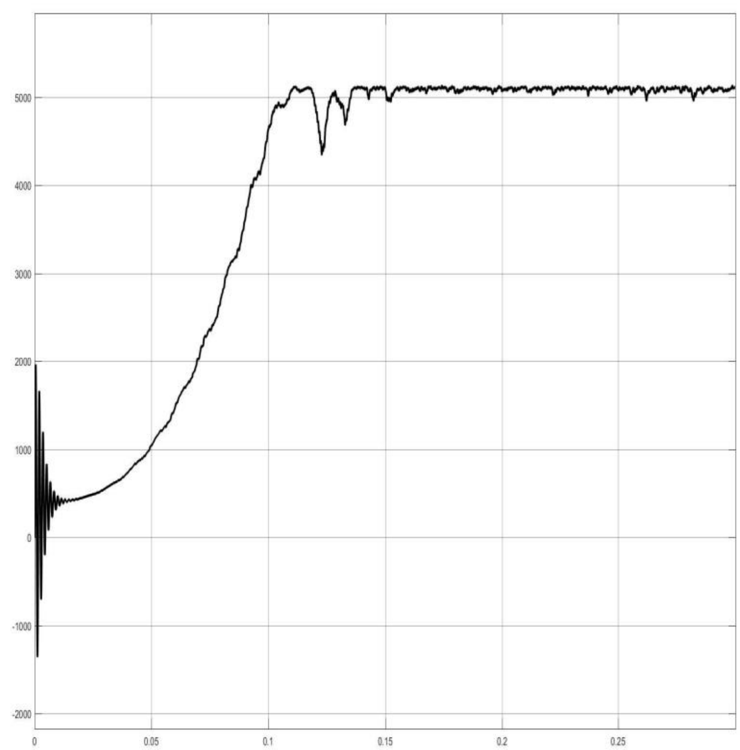


Fig. 6. Performance of MPPT P&O Algorithm for PV Array 02

B. Implementation of Multicarrier PWM technique in MATLAB/Simulink

The Below Fig. 7 shows Generic MATALB/Simulink model for the multicarrier PWM technique. This gives switching signal to the each H-bridge. This uses one reference sinusoidal wave and four carriers triangular waves to generate switching signal for CHB five level inverter.

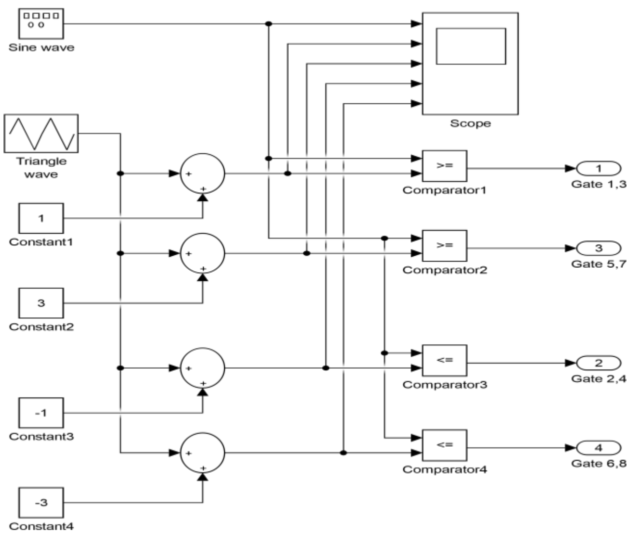


Fig. 7 MATLAB/Simulink model of multicarrier PWM

IV. SIMULATION RESULTS

The summary of obtained output voltage THD is given in the Table 5 and comparison of output voltage THD is given in Fig.8. For all multicarrier PWM technique i-e PDPWM, POD, APODPWM and PSPWM. It is observed that modulation index significant influence on total harmonic distortion. For all multicarrier modulation techniques at higher values of modulation index has less total harmonic distortion than lower values modulation index and also it is observed that as value of M.I increases power quality is improved and THD is decreased considerably. The total harmonic distortion for CHB five level inverter with PV system has equal for PDPWM, PODPWM and APOD modulation techniques. Whereas at unity modulation index POD and APOD has more total harmonic distortion. For phase shifted PWM modulation technique observed that it has low total harmonic distortion in comparison to other modulation technique for CHB five level inverter when interfaced with PV system.

V. CONCLUSION

In this work a stand-alone solar photovoltaic system is simulated along with cascaded H-bridge five level inverter. Multicarrier PWM modulation technique is implemented for the switching of CHB five level inverter and P&O algorithm in combination of dc dc boost converter is implemented the maximum power point tracking. Individual bridge has separate maximum power tracking and control. The PV system model is simulated in the linear region of the modulation index i-e 0.7 to 1.0 for popular multicarrier based PWM modulation techniques that is PDPWM, PODPWM, APODPWM and PSPWM. It is observed that for the low modulation index all the multicarrier modulation techniques i-e PDPWM, PODPWM, APODPWM and PSPWM gives poor THD but the PSPWM has better THD than other modulation techniques. All the carrier has good THD result at unity modulation index and poor THD at lower value of modulation index.

TABLE V: Output voltage THD

Carrier technique	Modulation Index			
	0.7	0.8	0.9	1.0
	THD			
PDPWM	52.80	46.73	38.65	29.41
PODPWM	52.76	46.69	38.68	29.41
APODPWM	52.80	46.76	38.64	29.34
PSPWM	41.89	38.40	33.50	27.01

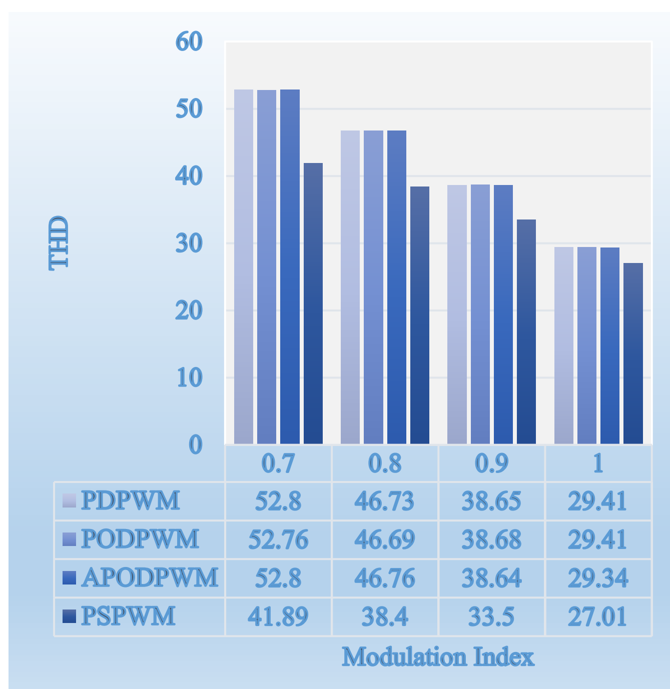


Fig. 8. Comparisons of results

REFERENCES

[1] Morya Ajay Kumar, Anshuman Shukla and Suryanarayana Doolla “Control of Grid Connected Cascaded H-Bridge Multilevel Converter During Grid Voltage Unbalance for Photovoltaic Application” IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society, Vienna, 7990-7995 2013.

[2] Strache Sebastian, Ralf Wunderlich and Stefan Heinen “A Comprehensive, Quantitative Comparison of Inverter Architectures for Various PV Systems, PV Cells, and Irradiance Profiles” IEEE transactions on sustainable energy, vol. 5, no. 3, july 2014.

[3] Mittal Nupur et.al “Multilevel Inverters: A Literature Survey on Topologies and Control Strategies” IEEE 2nd International Conference on Power, Control and Embedded Systems, Allahabad, 1-11. 2012.

[4] M. Coppola et.al “Modulation Technique for Grid-Tied PV Multilevel Inverter” IEEE International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), Anacapri, 923-928. 2016.

[5] Colak Ilhami et.al “The Design and Analysis of a 5-Level Cascaded Voltage Source Inverter with Low THD” IEEE International Conference on Power Engineering, Energy and Electrical Drives, Lisbon, 575-580. 2009.

[6] McGrath Brendan Peter and Donald Grahame Holmes “Multicarrier PWM Strategies for Multilevel Inverters” IEEE Transactions on Industrial Electronics, vol. 49, no. 4, pp. 858-867, Aug. 2002.

[7] Villalva Marcelo Gradella, Jonas Rafael Gazoli, and Ernesto Ruppert Filho “analysis and simulation of the P&O mppt algorithm using a linearized pv array model” 35th Annual Conference of IEEE Industrial Electronics, Porto, 231-236 2009.

[8] Rajput, Rimsha Musharraf, Nabeela Amjad Sidhu, and Zuhra Khan Zaur. "Design and Implementation of Maximum Power Point Tracker and Grid-Tied Voltage Source Inverter." International Journal of Electrical Engineering & Emerging Technology (IJEEET)" vol.1, No.1, pp.7-10, 2018.

[9] Mustafa, Imran, and Kanwal Naz. "Modified Perturb and Observe MPPT Algorithm for PV System under Fast-Changing Environmental Conditions. International Journal of Electrical Engineering & Emerging Technology (IJEEET)" vol.1, No.1, pp.30-36, 2018.

[10] Hassan A. Khan and Saad Pervaiz “Technological review on solar PV in Pakistan: Scope, practices and recommendations for optimized system design” Renewable and Sustainable Energy Reviews VOL.23, pp.147–154 2013.

[11] Villanueva Elena et.al “Control of a Single-Phase Cascaded H-Bridge Multilevel Inverter for Grid Connected Photovoltaic Systems” IEEE Transactions On Industrial Electronics, Vol. 56, No. 11, November 2009.

[12] Sekar G Leo, Dr. R. Jayapal and C.K Shankar “Advancement In Multilevel Vsi For Stand-Alone Solar PV System” IEEE International Conference on Energy Efficient Technologies for Sustainability (ICEETS), Nagercoil, 89-95. 2016.

[13] Patil S.N and R. C. Prasad “Design and Development of MPPT Algorithm for High Efficient Dc-Dc Converter for Solar Energy System Connected to Grid” IEEE International Conference on Computer, Communication and Control (IC4), Indore, 1-7. 2015.

[14] Chuang Wang et.al “Photovoltaic Multilevel Inverter with Distributed Maximum Power Point Tracking and Dynamic Circuit Reconfiguration 3rd International Future Energy Electronics Conference and ECCE Asia (IFEEC 2017 - ECCE Asia), Kaohsiung, 1520-1525. 2017.

[15] Dabas Tanuj and Ram Avtar “THD Analysis of Cascaded H-Bridge With Level Shifted Multicarrier Modulation” Advances in Computer Science and Information Technology (ACSIT) Volume 2, Number 7; pp 92 – 96 April – June, 2015.

[16] Priya Tyagi1 and Rakeshwri Agrawal “Comprehensive Analysis And Simulation Of Multilevel Power Converters To Curtail Total Harmonic Distortion” Electrical & Computer Engineering: An International Journal (ECIJ) Volume 4, Number 3, September 2015.

[17] Sangeetha R Gupta, Dr.Anitha G.S “Open Loop AnalysisOf Cascaded Hbridge Multilevel Inverter Using PDPWM for Photovoltaic Systems” International Journal of Technical Research and Applications Volume 3, Issue 4 PP. 05-07 July-August 2015.

[18] Mahar, Mukhtiar Ahmed, Muhammad Aslam Uqaili, and Abdul Sattar Larik. "Harmonic analysis of ac-dc topologies and their impacts on power systems." Mehran University Research Journal of Engineering & Technology 30, no. 1 (2011): 173-178.

[19] Darus Rosheila et.al “Comparison Phase shifted and Level shifted PWM in the Modular multilevel converter” IEE International Power Electronics Conference (IPEC-Hiroshima 2014 - ECCE ASIA), Hiroshima, 3764-3770. 2014.

[20] Mauricio Angulo et.al “Level-shifted PWM for Cascaded Multilevel Inverters with Even Power Distribution” Power Electronics Specialists Conference, Orlando, FL, 2373-2378. 2007.

[21] Roozbeh Naderi and Abdolreza Rahmati “Phase-Shifted Carrier PWM Technique for General Cascaded Inverters” IEEE Transactions On Power Electronics, Vol. 23, No. 3, May 2008.

[22] Sk.Raffi And R.Srikanth “Harmonics Reduction By Multicarrier PWM Techniques For Cascaded H-Bridge Inverter” International Journal Computer Technology & Applications, Vol 7 (1),pp 152-161 IJCTA 2016.

[23] D. Patel et.al "A review of various carrier based PWM methods for multilevel inverter," India International Conference on Power Electronics 2010 (IICPE2010) pp. 1-6 2011.