THD analysis and design of filter combinations in 13 level cascaded H bridge with 1-phase half bridge LDN in multilevel inverter

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Abstract. The study of total harmonic distortion is the important factor in power electronic devices for predominately calculations and it is effects the technical issues and cost functions. The 13 level Cascaded H bridge with 1-Phase half Bridge LDN networks improving for effectiveness of analysis in THD. This paper main objective is finding the harmonic analysis with different frequencies by using data sheets and MATLAB circuits learning process. The simulation results obtained using Cascaded H bridge with LDN method for producing the 13 level output related to different THD values with different frequencies changing the load parameter values. This system explains about differences between two methods and reducing the no of switches for developing same output values, but THD values are important for design of filter combinations in power electronic devices and it is changes at different frequencies with amplitude values. THD analysed with SPWM method in multilevel inverter.

Keywords. LDN, Multilevel inverter, PWM, THD

1. Introduction
The applications of multi level inverter are using widely in power systems for controlling medium voltage and high-power level has significance during previous years[1]. The various models are used in power electronic switches can help in requiring the different topologies in multilevel inverter for modern applications. Due to this developed various papers work producing the better consumption of power levels of these topologies for various applications[3-10]. Basically multilevel inverters are three types those are Diode clamped, flying capacitor and Cascaded H bridge. Based on the operation,
model structure Cascaded H bridge inverter is having more benefits to the other topology methods. Cascaded H bridge multi level inverter is having series or cascaded structure of number of H bridge[2]. This method is used to synthesize the desired AC output voltage from different DC voltages are connected to respect H bridges and producing with its own isolated DC supply[7].

The power losses in an inverter circuit having switching losses, conduction losses, snubber losses, and off state losses, when we are considering off state mode leakage currents, power losses, snubber losses are treated as negligible in IGBT’s. So, it is important and challenging to operate the inverter circuit with less harmonic analysis and power losses[8-9].

The main objective of this power electronic circuit is minimize the THD and DC source voltages to produce the desired fundamental output with good efficiency with changing of amplitude and frequencies. So THD analysis and power losses in circuit are very important for minimize the different losses. Some circuits are using harmonic search it is easy to implement and can be applied to reducing higher order harmonics[6].

Different methods have been implemented some papers to evaluate the power losses, switching losses in multilevel inverter. These type of problem we can eliminated by perform calculation analysis with simulation circuits in mat labs and require some mathematical analysis and evolution process. Proper selection of modulation techniques are very important for reduction of THD values in multilevel inverter[4-11]. Those are multilevel inverter controlled using traditional methods, carrier based pulse width modulation techniques, sinusoidal pulse width modulation, space vector modulation techniques. In these techniques switching losses are very important and depends upon switching frequency values[9-22]. If we are going to reducing the switching frequency is not possible directly so that purpose we are using the filter action for reducing the harmonic content in the output voltage waveforms.

The estimation of switching and conduction times for each switches is very slow process and it takes lengthy calculations in mind for that situations some papers are developed the modern calculations to simplify the action of power losses evolution process[5]. The selective harmonic elimination method using the low power consumption and gives the high output power quality to minimize the harmonics with reducing the power losses.

1.1 Contribution of the paper
- Implemented the new LDN network in Cascaded H bridge Multi level inverter.
- Analysed the Different THD values with changing of frequency switching.

2. System description

Figure 1.13 Level cascaded H bridge with 1-phase half bridge LDN multilevel inverter.
In this figure 1 shows circuit diagram for 13 Level Cascaded H Bridge with 1- Phase half bridge LDN network. This inverter is having four Dc voltage sources Vdc1, Vdc2, Vdc3, Vdc4/2), 12 H bridge switches (H1,H2,H3,H4,H5,H6,H7,H8,H9,H10,H11,H12) and two LDN single phase half bridge switches (Ls1,Ls2).

In this power electronic circuit developed with LDN network in cascaded H Bridge multi level inverter. LDN is nothing but Level Doubling Network is used to increase the output voltage levels of multilevel inverter with reducing the less no of switches. In order to reducing the no of switches in power electronic circuit the loss of the system is reduced, so it is one of the best method for reducing the switch count devices.

| S—> | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | H9 | H10 | H11 | H12 | Ls1 | Ls2 |
|-----|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|
| 20V | F  | T  | F  | T  | T  | T  | F  | T  | F  | F   | T   |     |     |     |
| 15V | F  | T  | F  | T  | T  | T  | F  | T  | F  | F   | T   |     |     |     |
| 10V | F  | T  | F  | T  | F  | T  | F  | T  | F  | F   | T   |     |     |     |
| 5V  | F  | T  | F  | T  | F  | T  | F  | T  | F  | T   | F   |     |     |     |
| 0V  | F  | T  | F  | T  | F  | T  | F  | T  | F  | F   | T   |     |     |     |
| -5V | F  | T  | F  | T  | F  | T  | F  | T  | F  | T   | F   |     |     |     |
| -10V| F  | T  | F  | T  | F  | T  | F  | T  | F  | T   | F   |     |     |     |
| -15V| F  | T  | F  | T  | F  | T  | F  | T  | F  | T   | F   |     |     |     |
| -20V| F  | T  | F  | T  | F  | T  | F  | T  | F  | T   | F   |     |     |     |

S: Switches
V: Voltage
T: On
F: Off

In this table 1 shows the switch conduction modes at different voltages. When we applied +5V at that time 6H Bridge switches and one LDN network switches (H2,H4,H6,H8,H10,H12,Ls1) operated. If we applied -5v to the system again operated same no of switches but sequence is different that is (H2,H4,H6,H8,H11,H12,Ls1) in this way we using the different voltages at various switches operating simultaneously.

2.1 Operation of the inverter circuit
In this multilevel inverter circuit operating at different modes in positive half cycle mode some switches are working and negative half cycle mode remaining switches are working. If Vref≥6V some active H Bridge switches and LDN switch working on position (H1,H2,H5,H6,H9,H10,Ls2). When Vref≥5V then some active H Bridges switches and LDN switches are turn on(H4,H2,H5,H6,H9,H10,Ls1).If Vref≥4vc at that time some active switches are operating turn on (H2,H4,H5,H6,H9,H10,Ls2), If Vref≥3vc some active H Bridges switches and LDN switch turn on (H2,H4,H6,H8,H9,H10,Ls1), If Vref≥2vc some active H Bridges switches and LDN switch turn on (H2,H4,H6,H8,H9,H10,Ls2), If Vref≥vc some active H Bridges switches and LDN switch turn on
If \( V_{	ext{ef}} \geq -V_c \) some active H Bridge switches and LDN switch turn on (H2,H3,H4,H7,H8,H11,H12,Ls1,Ls2).

2.2 MATLAB simulation circuit

![MATLAB simulation circuit](image)

**Figure 2.13** 13 level cascaded h bridge with single phase half bridge LDN simulation circuit.

In this figure 2 shows the simulation circuit for implemented system. The system is having upper 12 switches represents the Cascaded H bridge Multilevel inverter switches below 2 switches represents the LDN network. The LDN model is used to increase the Dc voltage with less no of switches for producing the desired output values. By using this system improved the analysis about different THD values with changing of load parameters and switching frequencies.
3. Results

**Figure 3.** MATLAB results cascaded H Bridge with 1-phase half Bridge LDN network.

In this figure 3 shows the results about desired 13 level cascaded H Bridge inverter with 1-phase half bridge LDN network. By using the mat lab circuits we can generate the output voltage and THD value. In this inverter circuit we can generate the same THD value at two different methods one is Cascaded H bridge with out LDN network and second one using cascaded H bridge inverter with 1-phase half Bridge LDN network produced same THD values and output voltages.

4. Analysis of THD

**Table 2.** Harmonic analysis with LDN 5 volts

| Modulation Index | Switching Frequency | Cascaded volt | LDN volt | % THD | Harmonic analysis |
|------------------|---------------------|---------------|----------|-------|------------------|
| 1                | 5000                | 20            | 05       | 12.42 | Less lower order |
| 0.8              | 5000                | 20            | 05       | 15.27 |                  |
| 1                | 1000                | 20            | 05       | 10.68 |                  |
| 1                | 500                 | 20            | 05       | 10.73 |                  |
| 1                | 50                  | 20            | 05       | 8.80  |                  |

**Table 3.** Harmonic analysis with LDN 10 volts

| Modulation Index | Switching Frequency | Cascaded volt | LDN volt | % THD | Harmonic analysis |
|------------------|---------------------|---------------|----------|-------|------------------|
| 1                | 50                  | 20            | 10       | 6.62  | 13th=1.42, 3rd=0.8 |
| 1                | 500                 | 20            | 10       | 9.43  |                  |
| 1                | 1000                | 20            | 10       | 9.40  |                  |
| 1                | 1500                | 20            | 10       | 8.79  | 4,6,27,24=>1%     |
Table 4. Harmonic analysis with LDN 15 volts

| Modulation Index | Switching Frequency | Cascaded volts | LDN volts | %THD | Harmonic analysis |
|------------------|---------------------|----------------|-----------|------|------------------|
| 1                | 5000                | 20             | 15        | 12.33| Lower less       |
|                  |                     |                |           |      | Only 5000 is     |
|                  |                     |                |           |      | at 8% less1.5    |
| 0.8              | 5000                | 20             | 15        | 12.33|                  |
| 1                | 1000                | 20             | 15        | 11.41|                  |
| 1                | 50                  | 20             | 15        | 11.28|                  |
| 1                | 10000               | 20             | 15        | 8.78 |                  |
|                  |                     |                |           | 19.31|                  |

In the tables 2, 3 and 4 shows the THD analysis in 13 level Cascaded H Bridge inverter with LDN 5V, 10V and 15V. The system can produced the different THD values at various switching frequencies and amplitude value. The THD values are changing with switching frequencies and amplitudes. From the above tables it is observed that % THD is more when LDN voltage is 5 V as compared with LDN voltages 10V and 15V, we can analyzed the THD values that is LDN voltage is 5 volts having higher THD values compared to LDN voltage 10volts. Based on that analysis we can designed the filter construction and cost effective of the multilevel inverter circuit.
The figures 4, 5 and 6 show the %THD values at LDN 5 volts with different switching frequencies and various amplitude values. At switching frequency is 5000Hz having THD value is 12.42% and switching frequency is 1000Hz having THD value is 10.48% and when we are changing switching frequency 50Hz at that time THD value 8.80%. Based on these changing THD values are different at various amplitude and frequency values.
The figures 7 and 8 shows the THD values at LDN 10 volts with different switching frequencies and various amplitude values. At switching frequency is 50Hz having THD value is 6.62% and switching frequency is 500Hz having THD value is 9.43% and when we are changing switching frequency 50Hz at that time THD value 8.80%. Based on these changing THD values are different at various amplitude and frequency values.

**Figure 8.** %THD at switching frequency (fs)=500Hz.

**Figure 9.** %THD at switching frequency (fs)=500Hz.
The figures 9, 10 and 11 shows the THD values at LDN 15 volts with different switching frequencies and various amplitude values. At switching frequency is 5000Hz having THD value is 12.33% and switching frequency is 50Hz having THD value is 8.78% and when we are changing switching frequency 10000Hz at that time THD value 19.31%. Based on these changing THD values are different at various amplitude and frequency values.

5. Conclusion
In this paper presents the 13-level cascaded H bridge with 1-phase half bridge LDN multilevel inverter. The LDN network is the one of the best method for reducing the no of switches and increase DC voltages with less circuit. The MATLAB inverter circuit producing the desired 13 level output and different THD values at various amplitude and different frequencies. By using this inverter circuits we can analyzed the better THD values and design of filter combinations, economical to the inverter circuit. we applied the different LDN voltages 5V, 10V and 15V at different frequencies then evaluating the different THD values.
6. References

[1] McGrath B P 2002 Multicarrier PWM strategies for multilevel inverters IEEE Trans. Ind.Electron49(4) 858-867

[2] Villanueva E, Correa P and Pacas 2009 Control of a single phase cascaded H-bridge multilevel inverter for grid connected photovoltaic systems IEEE Trans. Industrial Electronics564399-4406

[3] Kangarlulu M F and Babaei E 2013 A generalized cascaded multilevel inverter using series connection of submultilevel inverters IEEE Trans. Power Electron28(2) 625-636

[4] Arulmurugan R 2018 Photovoltaic powered transformer less hybrid converter with active filter for harmonic and reactive power compensation ECTI Trans.Electr. Eng.Electron Commun.16(2) 44-51

[5] Bhaskar J and Rajeshkar Reddy K 2016 A unified control strategy for neutral point clamped inverter International Journal and Innovation Research07 2348-2370

[6] Swathi A and Sathyavani B 2016 Nine-level inverter capable of power factor control with DC-link switches International Journal of Innovative Technologies4(2) 236-240

[7] Karampuri R, Jain S and Somasekhar VT 2019 Common-mode current elimination PWM strategy along with current ripple reduction for open-winding five-phase induction motor drive IEEE Trans. Power Electron34(7) 6659-68

[8] Rajababu D and Raghu Ram K 2019 Voltage control strategy for three-phase inverter connected standalone wind energy conversion systems Int. J.Innov. Technol.Explo. Eng.8(11) 2164-2168

[9] Sathyavani B, Rajababu D and Sudhakar A V V 2019 Construction of a pure sine wave inverter International Journal of Innovative Technology and Exploring Engineering 8(9) 2278-3075

[10] Reshma B and Sathyavani B A multilevel converter with a floating bridge for open-endwinding motor drive International Journal of Innovative Research in Technology4(3) 2349-6002

[11] Rajababu D, Sudhakar AVV and Sathyavani B 2019 Development of technology for highpower industry converters Int. J.Innov. Technol.Explo. Eng. 8(10) 3130-3132

[12] Vedik B, Shiva C K and Harish P 2020 Reverse harmonic load flow analysis using an evolutionary technique SN Appl. Sci. 2 1584 https://doi.org/10.1007/s42452-020-03408-4

[13] Vedik B, Ritesh K, Deshmukh R and Shiva C K 2020 Renewable energy based load frequency stabilization of interconnected power systems using quasi-oppositional dragonfly algorithm J Control Autom.Electr Syst. https://doi.org/10.1007/s40313-020-00643-3

[14] Vedik B, Naveen P and Shiva C K 2020 A novel disruption based symbiotic organisms search to solve economic dispatch Evol. Intel. https://doi.org/10.1007/s12065-020-00506-5

[15] Kumar R, Sahu B, Shiva C K and Rajender B 2020 A control topology for frequency regulation capability in a grid integrated PV system Archives of Electrical Engineering69(2)389-401

[16] Basetti V, Chandel A K and Subramanyam K B 2018 Power system static state estimation using JADE-adaptive differential evolution technique Soft Computing 22(21) 7157-76 https://doi.org/10.1007/s00500-017-2715-3

[17] Shiva C K, Vedik B and Kumar R 2019 Integration of distributed power sources to hydro-hydro power system subjected to load frequency stabilization International Journal of Engineering and Advanced Technology8(2) 128-32

[18] Pasha SN, Harshavardhan A, Ramesh D and Md S Shabana 2019 Variation analysis of artificial intelligence machine learning and advantages of deep architectures International Journal of Advanced Science and Technology28(17) 488-495

[19] Swathi N, Padmaja Ch and Navya Jyothi G 2020 Audio assistive for blind people to identify the cloth patterns and colors Journal of Critical Reviews7(17) 154-158 10.31838/jcr.07.17.23

[20] Prakash TC, Mamatha M and Samala S 2020 An IoT based under weather monitoring system Journal of Critical Reviews7(17) 148-153 10.31838/jcr.07.17.22
[21] Kumar CN and Satyanarayana N 2015 Hybrid loss recovery technique for multipath load balancing in MANETs 2nd International Conference on Electronics and Communication Systems ICECS 2015 1294-1301 10.1109/ECS.2015.7124793

[22] Sekhar VM Rao, KVG Rao NS and Chand MG 2016 Comparing the capacity NCC and fidelity of various quantization intervals on DWT Advances in Intelligent Systems and Computing 413 45-55 10.1007/978-981-10-0419-3_6