

PERFORMANCE ANALYSIS OF CASCADED MULTILEVEL INVERTER WITH PI AND NEURAL TECHNIQUES FOR AGRICULTURAL PURPOSE

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Abstract— Harmonic content and Total Harmonic Distortion (THD) are the major power quality issue in electrical power system. Similarly harmonics are the non-integer multiples of the fundamental frequency. The performance of multi level inverter is analysed with PI and neural network controller with open loop and closed loop control. The open loop, conventional PI and neural network are designed for closed loop control of cascaded multilevel inverter to reduce the harmonics. The comparison is made for open loop and closed loop with PI and neural network. The comparison results reveal that the THD is reduced to about less than 5% with neural network control compared to open loop control. Switching angles can be calculated by neural network technique and this method is suitable for real-time applications. Particularly used in agricultural field with irrigation purpose. This method can be applied for any levels of multilevel inverter, The performance is analyzed with matlab simulink MATLAB 7.8

Keywords— Multi-level inverter, Total Harmonic Distortion (THD), PI controller, Neural Network (NN), and Modulation Index (M)

I. INTRODUCTION

To convert DC voltage into AC voltage inverters are used. Many types of inverters are available. The types are: a)Single phase inverters, b)Three phase inverters. Based on the voltage and current it is further divided into voltage source inverter and current source inverter. It can be able to control their frequency and output voltage simultaneously. And other functions they involved in reduce the load current harmonics. From the following features it can be used fuel cells, solar panel and also used in industrial applications. UPS(uninterruptible power supply),VFD(variable frequency drives) and also used in hybrid electric vehicles.

The proposed inverter it can be able to reduce the harmonic components using sinusoidal PWM technique [4] under the condition of identical DC sources with sinusoidal PWM technique. The comparison is also made for open-loop, closed-loop PI and Neural implementing sinusoidal PWM technique. The control scheme involves the generation of PWM pattern for the range of modulation index (m) between 0.1 to 1. The closed loop control of cascaded multilevel inverter is done by implementing conventional PI controller.

II. CASCADED MULTILEVEL INVERTER

The best method of multi level inverter is cascaded multi level inverter. It uses H-bridge in series. It may be single phase or full bridge inverter units. This H-bridge multi level inverter uses diodes and switches. This inverter basically needs three switches. The multi level inverter has several features in that important one is from the different direct current sources we can able to synthesize.

A. Multilevel Inverter

Many types of multilevel inverters are available. Cascaded multi level inverter is used for this work. Nine level inverter is connected in series with four single phase H-bridges. The number of ridges required for m level inverter is $((m-1)/2)$. Based on the fundamental frequency alone the switches are operated. Voltage stress is calculated by DC source voltage magnitude.

In the cascaded multilevel two or more than the inverters are connected in series. In order to provide better operation isolation is must. four DC sources are needed for nine level inverter. The proposed system has the main concept of using H-Bridge Inverter four level is for the identical Direct Current voltages. The bridge configuration uses power semiconducting switches for its operation.

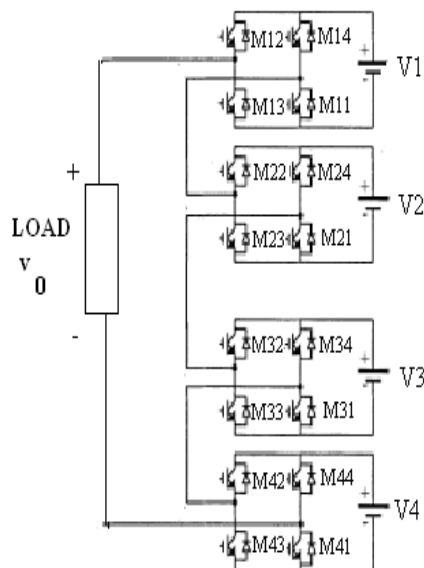


Figure. 1 single phase cascaded inverter

B. Method of Working

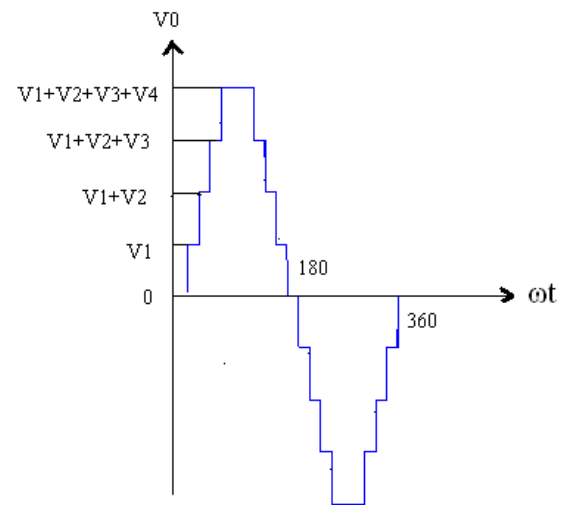


Figure .2 Output voltage of single phase inverter

The procedure involved in output voltage of nine level inverter is,

1. The output voltage level $V_0 = V_1$, turn on the switches M_{11} , M_{12} , M_{22} , M_{32} and M_{42} .
2. The output voltage level $V_0 = V_1+V_2$, turn on all the switches as mentioned in step 1 and M_{21} .
3. The output voltage level $V_0 = V_1+V_2+V_3$, turn on all the switches as mentioned in step 2 and M_{31} .
4. The output voltage level $V_0 = V_1+V_2+V_3+V_4$, turn on all the switches mentioned in step 3 and M_{41} .

III. HARMONIC ELIMINATION METHOD

The power electronic devices such as converters, inverters uses switching devices. The operation of these devices produce current and voltage harmonics in to the system. These harmonics affects the operation of equipments. Voltages harmonics are eliminated by series active filters. And current harmonics are eliminated by shunt active filters. The harmonics are reduced by PWM techniques are described in the below sections.

A. Importance of PWM Control

The PWM control methods the performance are mainly focused on some parameters such as : a) maximum inverter output voltage for the given DC Voltage b) load current having peak to peak value, c) switching losses of inverter , d) high THD of the current and voltage value. PWM technique depends upon the possible harmonic content in the inverter output voltage. From above mentioned PWM control methods are applied in the proposed inverter since it has various advantages over other techniques. The most important method is Sinusoidal PWM it works easier and make simple In controlling the amplitude and the frequency atlast it can able to reduce the output voltage harmonic content. [6].

In order to find out the modulation techniques, the formula has been used

$$\text{Modulation index (M)} = A_r/A_c$$

Where,

A_r = reference signal

A_c = carrier signal.

B. Switching Angles

The quarter wave symmetric is as assumed as the HESA . The expression for the H-Bridge multilevel inverter using quarter wave symmetric is given below

$$V_{(wt)} = \sum_{n=1}^{\infty} \frac{4V_{dc}}{n\pi} \left[\sum_{k=1}^s \cos(n\theta_k) \right] \sin(nwt) \quad (1)$$

Where the conditions for optimized switching angles are,

$$\theta_1 < \theta_2 < \dots < \theta_s < \frac{\pi}{2} \quad (2)$$

odd harmonic components are represented by

$$h_{(n)} \frac{4V_{dc}}{n\pi} \sum_{k=1}^s \cos(n\theta_k) \quad (3)$$

Modulation index

$$M = \frac{\pi V_1}{4V_{dc}} \quad (4)$$

The resulting harmonic equations are

$$\frac{4V_{dc}}{\pi} [\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4)] = V_1 \quad (5)$$

$$[\cos(5\theta_1) + \cos(5\theta_2) + \cos(5\theta_3) + \cos(5\theta_4)] = 0 \quad (6)$$

$$[\cos(7\theta_1) + \cos(7\theta_2) + \cos(7\theta_3) + \cos(7\theta_4)] = 0 \quad (7)$$

$$[\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4)] = M \quad (8)$$

Newton Raphson method is used to calculate the odd number of harmonics.

IV. ARTIFICIAL NEURAL NETWORKS

It is a mathematical model used to get desired response in biological neural networks. It involves supervised learning and non supervised learning. A group of nodes interconnected to get neural network..

A. Feed Forward Network

The feed forward neural network as shown in Fig. 3, the feed forward neural network is very simple compared to others. Information moves only one direction. It consists of three nodes. Input node, output node, hidden node.

Input – Modulation Index

Output – Switching Angles

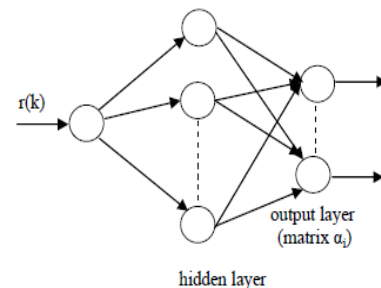


Fig. 3 Feed Forward Neural Network

B. Training of Neural Network Using MATLAB Coding neural network implementation for the flow chart representation as shown in fig. 4.

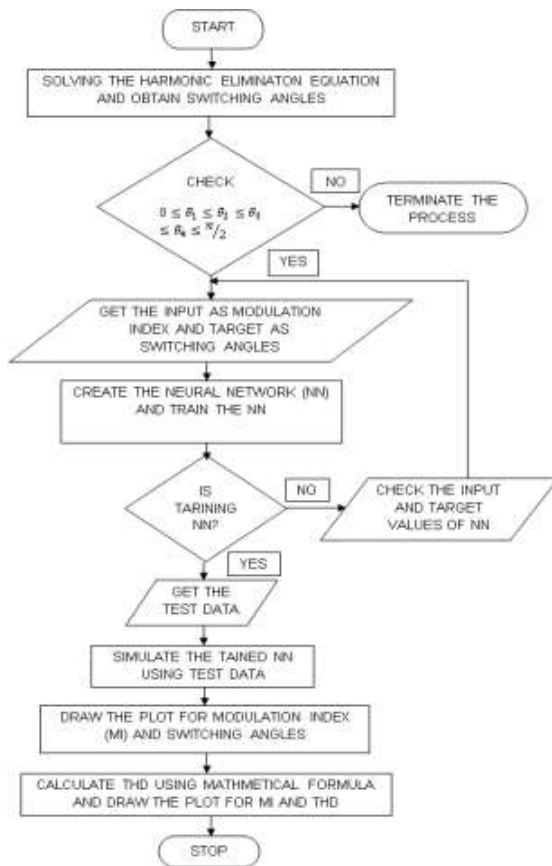


Fig. 4 Flow chart for proposed neural network technique

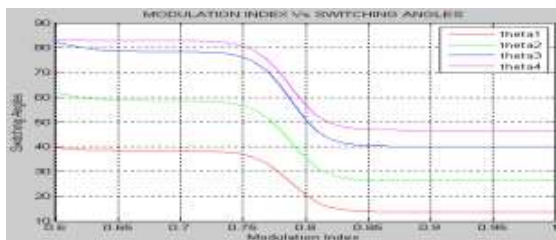


Fig. 5 Plot for Modulation index Vs corresponding Switching Angles

The figure 6 shows that the comparison between modulation rate and its calculated THD for their corresponding switching angles. The neural network is trained for 1000 epochs for the given set of inputs and target [19]

Table-I Switching angles for various modulation index and their respective THD values

Modulation Index	Switching Angles in degree				THD in %
	Theta 1	Theta 2	Theta 3	Theta 4	
0.8	21.67 14	35.24 25	48.16 18	55.00 73	4.2 10
0.81	18.54 23	30.89 42	42.59 96	49.89 68	4.1 9
0.82	16.62 33	28.22 99	39.20 14	46.77 17	4.0 8
0.83	15.58 80	26.79 31	37.37 05	45.08 74	3.9 4
0.84	15.06 80	26.07 16	36.45 10	44.24 15	3.9 2
0.85	14.81 64	25.72 22	36.00 55	43.83 18	3.8 3
0.86	14.69 67	25.55 59	35.79 33	43.63 67	3.8 56
0.87	14.64 02	25.47 75	35.69 31	43.54 46	3.7 8
0.88	14.61 37	25.44 07	35.64 60	43.50 13	3.7 54
0.89	14.60 13	25.42 34	35.62 39	43.48 10	3.7 3
0.9	14.59 54	25.41 53	35.61 35	43.47 15	3.6 11
0.91	14.59 27	25.41 15	35.60 86	43.46 70	3.5 36

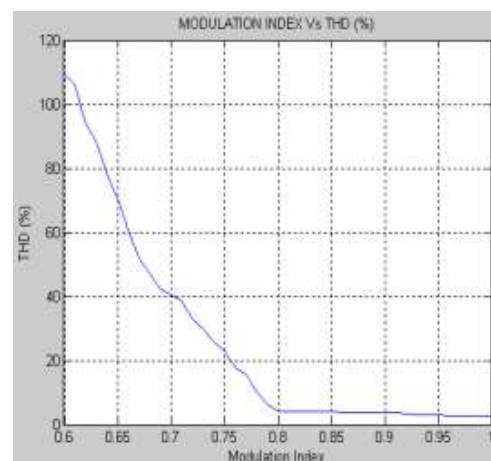


Fig. 6 Plot for Modulation index Vs THD in percentage

The switching angles for different modulation index and their corresponding THD values are shown in table-I. From that it has been inferred that the modulation index increases which results reduction of THD values.

V. SIMULATION RESULTS

The simulink model of the proposed nine level cascaded multilevel inverter systems for SPWM techniques with open loop, closed loop PI and neural implementation are described by following simulation diagrams.

A. Sinusoidal Pulse Width Modulation – Open Loop

The simulation was done for a cascaded nine level inverter with sinusoidal pulse width modulation is described in following figures 7. The gating signals generated using sinusoidal PWM technique is given to the power circuit switches to obtain the output voltage. The Figure.8 shows the simulated output voltage and current .

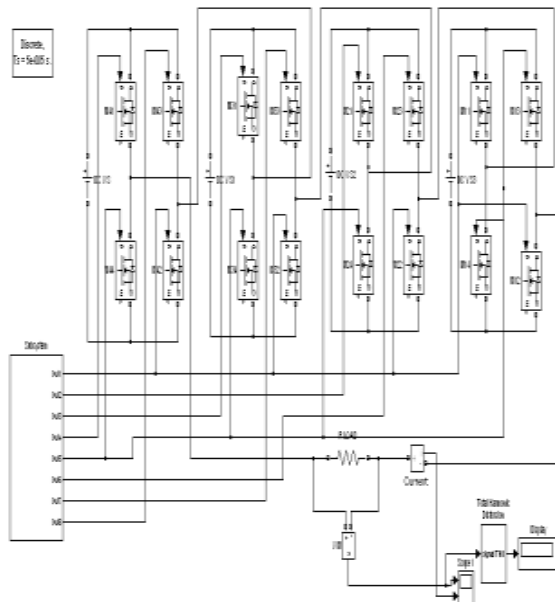
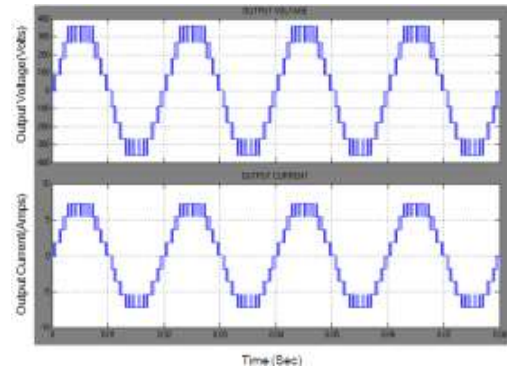


Figure 7. Simulation model of Multilevel Inverter



I. Fig. 8 output voltage and current waveform

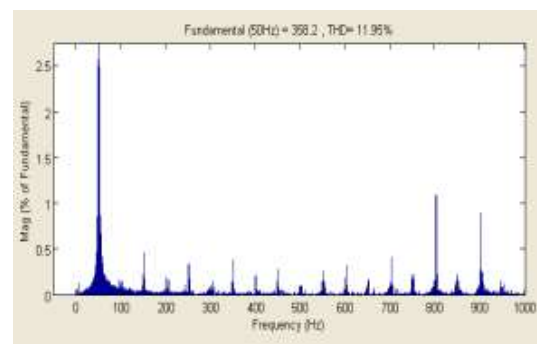


Fig. 9 Frequency Spectrum

B. Closed Loop - PI

In closed loop the control of inverter can be performed using conventional PI controller. The THD is measured for various values of m . The THD is found to be 4.21 % for $m = 0.85$.

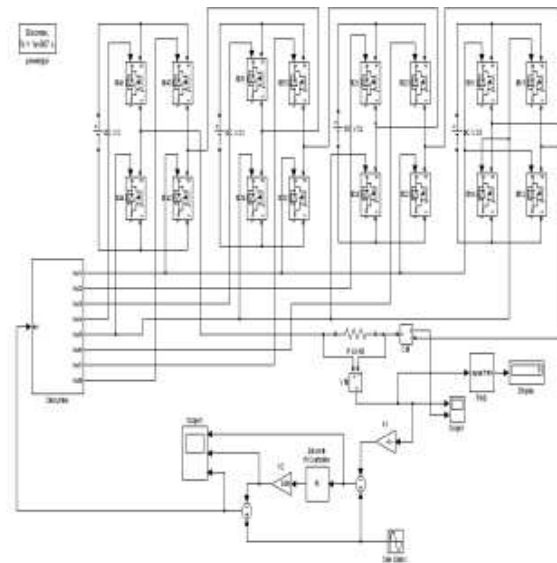


Fig. 10 Simulated circuit of the inverter (PI controller)

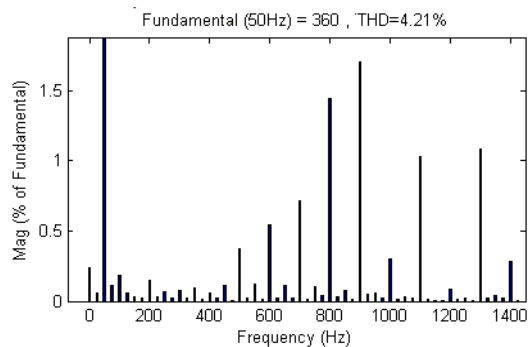


Fig. 11 Frequency spectrum of the output Voltage.

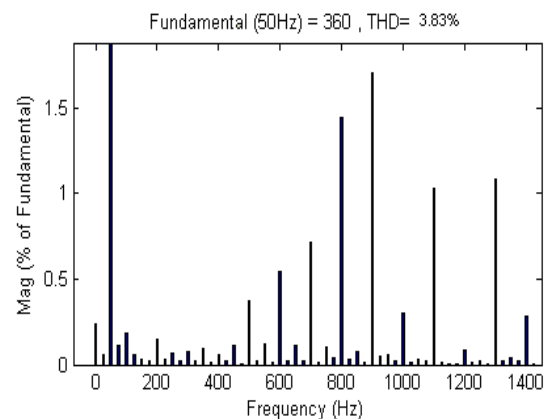


Fig. 13 Frequency Spectrum with ANN

C. Proposed scheme f with Neural Network

In view to confirm the validity of obtained results using the harmonics elimination technique with neural network, a test is carried out for $M=0.85$. The switching angles for test data are obtained from the neural network such as its output (switching angle). From that switching angles, the desired level of carrier signal levels are obtained.. These pulses are used to trigger the proposed inverter. The output voltage and current waveform and its harmonics spectrum are shown in figure 12, 13.

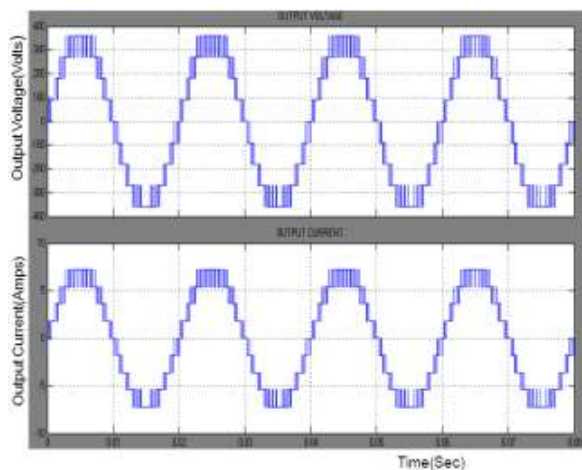


Fig. 12 output voltage and current waveform for sine PWM with ANN

D. Comparison Results

The Final results are obtained by comparing open and closed loop operation of cascaded multilevel inverter being used with sinusoidal PWM technique. The modulation index can be varied from 0.775 to 1. Figure.14 shows the graph of THD (%) Vs modulation index (m). The Total Harmonic Distortion (THD) is compared for open and closed loop with PI and neural network, the result obtain from neural is better response than other controller.

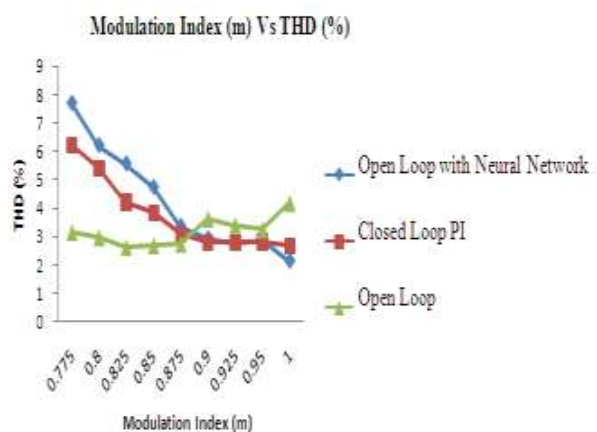


Fig. 14 Comparison of modulation index Vs THD for open loop, closed loop PI, neural network

IV. CONCLUSION

The proposed multilevel inverter performance is analyzed for open and closed loop with PI

controller and open loop neural network. The neural network gives the relationship between the switching angles and modulation rate with a feed forward network. The neural network based multilevel inverter provides high performance for increasing modulation index in the cascaded multilevel inverter. The variation of THD shows that the open loop of neural network control increases the system performance.

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