

Analytical Approach to Optimize the Waveform for Stepped Wave Inverter

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ABSTRACT

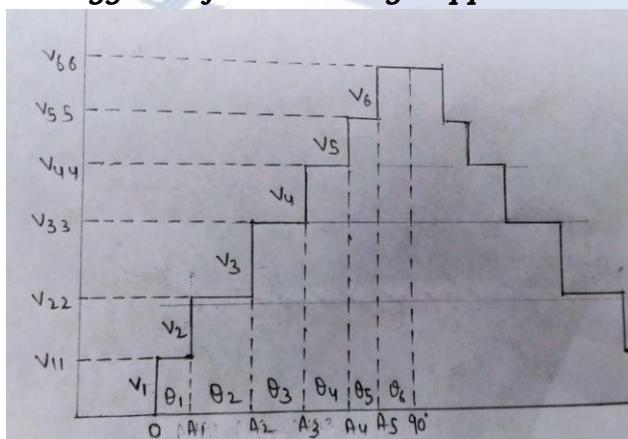
The stepped wave inverters got prominence due to their low THD and higher efficiency. The construction of an optimized waveform for a given multilevel inverter is very important aspect in design and performance analysis of inverter. In this paper by using a search algorithm, optimum parameters are found by constructing all the possible waveforms under given constraints and finding the optimized waveform with the least THD. With the help of a powerful computing software (Matlab) the search algorithm is implemented and the optimum parameters are obtained.

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I. INTRODUCTION

In this paper a simple analytical approach for finding the optimized waveform is presented. This is done by constructing different possible waveforms with in given limits and choosing the configuration with the least possible THD. This is done by a search algorithm presented.

Terminology used for describing stepped wave:



Step Angle (widths):

The angle at which the voltage rises or falls is called step angle. In the above diagram 0 represents the

initial position (0^0) and the length $0A_1$ represents the first step angle the angle $0A_1$ hereafter referred as θ_1 or ang1 or t_1 , similarly length A_1A_2 can also be referred as θ_2 or ang2 or t_2 and this also applies for all the other step angles. The above step wave is six level inverter waveform and for six level, six angles ($\theta_1 \theta_2 \theta_3 \theta_4 \theta_5 \theta_6$) exists and the sum of all step angles should be equal to 90^0 .

$$\theta_1 + \theta_2 + \theta_3 + \theta_4 + \theta_5 + \theta_6 = 90^0$$

Step voltage (heights):

Step voltage level or voltage level is the magnitude of the voltage for given step angle. It should be noted that its magnitude is confined to its step angle only. It also may be called as heights for the sake of simplicity.

From 0 to A_1 step voltage is V_1 , and from A_1 to A_2 step voltage is V_2 , similarly for other step angles also their respective step voltages exists as shown in the above figure.

The above waveform is quarter wave symmetric and hence all the mathematical analysis has been done up to 90^0 only.

II. INTRODUCTION TO SEARCH ALGORITHM

Algorithm Objective :

The aim of the algorithm is to find out the parameters for a step wave inverter which possess lowest THD , this is done by searching every possible combination that exists under the constraints given initially. By using this algorithm we can find the configuration of step wave with optimum parameters which will have least Total Harmonic Distortion (THD).

Description to design Process:

- Initially define the limits for step angle and voltage levels. Choose suitable voltage magnitudes and phase angles.
- Subject the parameters to a specific conditions. That is voltage and phase angle considerations for waveform construction.
- If the parameters satisfies the condition construct waveform and analyse the waveform.
- Calculate THD for the configuration. Check whether it is less than existing THD ,
- if yes make it as least THD and store the parameters for this configuration.
- Repeat the process until all the possible combinations is completed.
- Finally print the parameters and do harmonic analysis to the waveform produced.

The algorithm constructs all the possible waveforms and from these combinations the waveform with least THD is stored and also the parameters (heights and widths) for constructing the waveform are stored.since many possible combinations of waveforms can exists matlab software is being used.

Initially every step angle(width) and the voltage level(height) is given certain limits, for example angl1 is given between the limits 7 and 15, and similarly for other angles and voltage levels are given certain limits.and every limit is put in loop (for loop) so that it repeats within given interval.

Next step is construction of the waveform. We put some test condition for construction of the waveform that is, if sum of all the angles is equal to 90(quarter wave symmetry) and the sum of all the voltages is equal to 100 (or any other value depending on the required ac output voltage*) waveform is accepted.

Once waveform is successfully constructed the values of fundamental component and the rms value are calculated and the THD is computed.

Every time when THD is computed it checks whether calculated THD is less than the pre existing least THD value, if it is less than pre existing least THD , then it will be marked as least THD. This process will continue until all the loops are completed

If all the loops are completed then the parameters for least THD and the least THD value are printed The above algorithm is implemented in Matlab and the matlab program is given

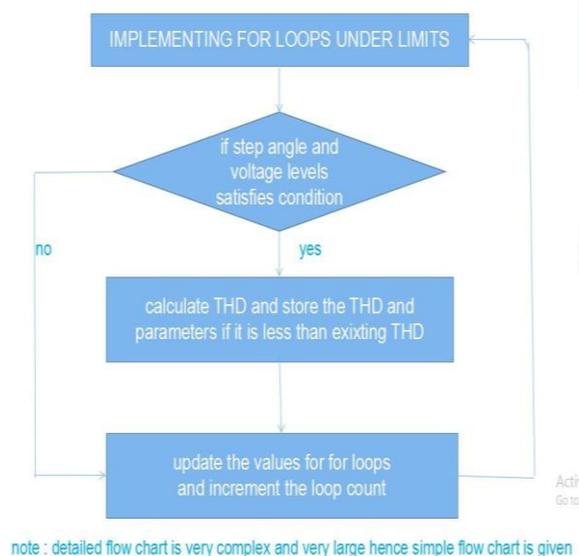
Matlab program for implementing algorithm:

For seven level inverter :

```

mine=9.5;q=0;nn=0;ss1=0;
% t represents angles (widths)
for t1=7:1:15
for t2=7:1:10
for t3=8:1:11
for t4=8:1:13
for t5=6:1:12
for t6=10:1:14
for t7=20:1:25
% v represents voltages (heights)
for v1=6:1:12
for v2=12:1:16
for v3=13:1:17
for v4=11:1:18
for v5=13:1:18
for v6=10:1:14
for v7=11:1:15
% checking if voltage and angle
satisfies condition
if(t1+t2+t3+t4+t5+t6+t7==90 &&
v1+v2+v3+v4+v5+v6+v7==100)
nn=nn+1;
v11=v1;
v22=v11+v2;
v33=v22+v3;
v44=v33+v4;
v55=v44+v5;
    
```

7.PROCESS FLOW CHART

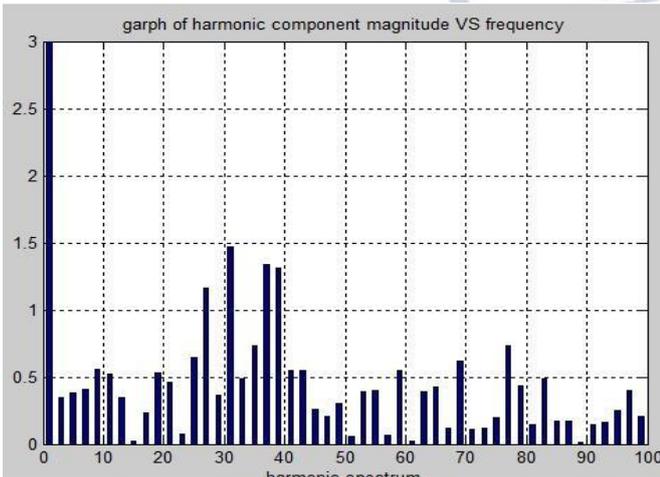


The Matlab program generated the above parameters for constructing the optimized waveform with THD of 5.6%

Analysis of the generated waveform :

The generated wave form has THD(total harmonic distortion) of 5.6% and the harmonic spectrum is as shown below

Harmonic magnitudes up to 100*f frequency (without filter)



has been observed that fundamental component has magnitude of 72.71 volt and the third, fifth, seventh, ninth and, eleventh harmonics have magnitude of 0.3429, 0.3850, 0.4120, 0.5549, 0.5206 respectively that is less than 1 volt and the 27, 31, 37 and 39 have harmonic magnitudes greater than 1 and those values are 1.16 ,1.47 ,1.34 ,1.31 respectively.

The above analysis is done for variable step(heights) voltages and can also be done for constant step.

If constant step voltage of 20 volt is taken for a seven level inverter least possible THD obtained is 6.01% with 103volt rms for fundamental component.

Choosing the step angles and voltage levels

The trail and error method should be employed while choosing the boundaries for the voltage and angle loops. Initially select boundaries with larger intervals for every loop, the calculation time may be higher and may give some optimum THD , observe the boundaries(limits) and change the limits according to the obtained results. Repeat the same process until least possible THD is same even on changing the boundaries(limits).if we observe an increasing THD then take another set of limits for 'for' loops and again repeat the above process until least THD is achieved.

The above analysis is done by considering the step voltages with different voltage levels is possible, this different voltage sources can be produced using controlled DC sources. The algorithm can be implemented with constant DC sources by finding optimum angles only for a given level inverter.

Control of output voltage :

In PWM technique output voltage can be controlled by changing the modulation index, but in present technique output voltage (wave from) is fixed and can not be changed so, it can not be used as variable frequency drive but can be used for small and domestic applications.

Uniform scaling of voltage steps(heights) can be used to get the required output voltage. For example multiplying the each and every voltage steps(heights) with 3.15 in the given matlab output will result in output voltage of 230 volt (rms) approximately with same THD of 5.6%. Implementing the algorithm for higher levels may significantly reduce THD. above analysis is done without using any filter and by using a suitable LC (low pass) filter,harmonics in the output voltage can be further reduced and lower THD can be attained

III. CONCLUSION

The multilevel inverter topology can overcome some of the limitations of the standard two-level inverter. Output voltage and power increase with number of levels and the total harmonic distortion (THD) will reduce significantly.

The search algorithm presented in this paper gave the successful results by generating the optimized waveform with the THD of 5.6 % for a seven level inverter and by using the filter circuit for an RL load gave the THD about 2.4 % for seven level inverter.

By increasing the number of levels the stepped waveform considerable decrease in the THD is observed and the results of the matlab program are shown below

Number of levels	THD
Five level inverter	7.8 %
Six level inverter	6.2 %
Seven level inverter	5.6%

Application of filter circuits will reduce the THD. A low pass filter (LC circuit) with proper L and C values (based on the maximum load) can be used

to reduce the reduce the effect of high frequency harmonics.

Scope :

The optimum parameters or the configuration of the waveform obtained by implementing the search algorithm can be constructed by cascaded DC source multilevel inverter which will give least possible THD and will give high efficiency for multilevel inverters. since need of high power and low THD inverters are increasingly getting importance in industrial and domestic applications , multi level inverters provide promising solution for reduction in harmonics and improving the efficiency.

Increase in the number of voltage steps can be used to reduce the THD and improve the efficiency

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