GENETIC ALGORITHM BASED SELECTIVE HARMONIC ELIMINATION TECHNIQUE FOR MULTILEVEL INVERTERS WITH UNEQUAL VOLTAGE SOURCES

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ABSTRACT:- Harmonics elimination in Multilevel inverters (MLIs) have been receiving immense attention for the past few decades for the reason that MLIs have the ability to synthesize a near sinusoidal output voltage wave with minimal total harmonic distortion (THD). Selective harmonic elimination (SHE) techniques can eliminate the objectionable lower order harmonics with low switching frequency by solving the Fourier non-linear transcendental equations of the output voltage. This paper proposes a Genetic Algorithm (GA) based SHE techniques to obtain the optimized switching pattern for various modulation index when the MLI is working with both equal and unequal dc sources. It worth noting that the angles optimized for equal voltage class will not work well for unequal class. This paper could be a study material for researchers in the field of PWM theory, which also describes in detail the procedure for implementing the MATLAB-GA toolbox based optimization of SHE switching angles. The optimization technique is presented for the MLI working with unequal dc input voltage sources. The informative simulation results verify the validity and effectiveness of the proposed algorithm.

Keywords- *Genetic Algorithm, multilevel inverter, unequal dc sources, selective harmonics elimination.*

1. INTRODUCTION

Multilevel inverters (MLIs) have drawn increasing attention in numerous applications, especially in the distributed energy resources area, because several fuel cells, batteries, solar cells, or micro-turbines or rectified wind turbines can be connected through a MLI to feed a load or interconnect to the ac grid without voltage balancing problems (Leon M. Tolbert,2002, M. Manjrekar and T. Lipo 1998, Leon M,1999, J. S. Lai and F. Z. Peng,1996, Wu Bin, Song Pinggang, 2004).The prominent MLI topologies are: (i) cascaded H-bridge MLI, (ii) diode-clamped MLI, and (iii) flying capacitor MLI. Cascaded H-bridge (CHB) MLI appears to be superior in terms of its simple and modular structure but also requires the least number of components by deducting the clamping diodes and voltage balancing capacitors compared with the other topologies. Selection of topology and sufficiency of number of levels are based on the application suitability and demands. After having chosen the topology and the number of levels, the switching strategy selection gets the importance since the switching strategy has direct influence on the harmonic contents of output voltage. A host of pulse width modulation (PWM) strategies have been developed, analysed and studied by researchers aiming variety of requirements.

In 1973, H.S.Patel and R.G.Hoft have originally proposed selective harmonic elimination PWM (SHEPWM). This generalized method developed for eliminating a fixed number of harmonics in the half-bridge and full-bridge inverter output waveforms and solutions are presented for eliminating up to five harmonics. The SHEPWM based inverters eliminate low order harmonics and operate at low switching frequency that result in reduced switching losses (H. S. Patel and R. G. Hoft,1973 & 1974).Traditional algorithms like Newton-Raphson (NR) algorithm are available for solving the non-transcendental equation to find switching angles for performing SHE. The major drawback in traditional methods is the selection of initial values, which is due the fact that the convergence of the algorithm depends on the initial values. Genetic Algorithms (GA) are a family of soft computational models inspired by biological evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome-like data structure and apply recombination operators to these structures as to preserve critical information. Genetic algorithms are often viewed as function optimizer, although the arrays of problem to which genetic algorithms have been applied are quite broad. An implementation of GA begins with a population of (typically random) chromosomes. Then it evaluates these structures and allocated reproductive opportunities in such a way that these chromosomes which represent a better solution to the target problem are given more chances to `reproduce' than those chromosomes which are poorer solutions. The 'goodness' of a solution is typically defined with respect to the current population.

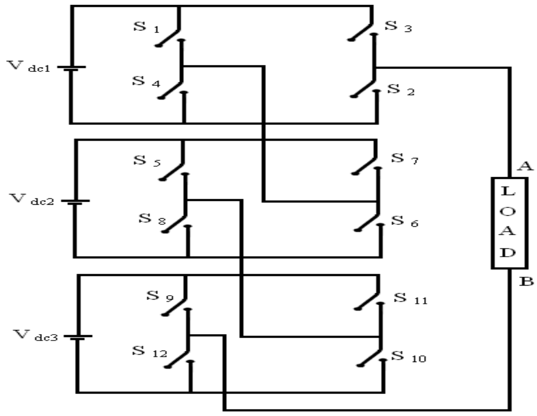
A.I.Maswood*et al.* has considered GA as the preferred solution of specific harmonic elimination switching pattern. The usual problem of the selection of starting values in numerical solution of a SHEPWM switching pattern is easily avoided. Hence, easy convergence and less computing-time are achieved (A. 1. Maswood, Shen Wei, and M. A. Rahman ,2001).In 2005, Burak Ozpineci*et al.* have applied the GA optimization technique to determine the switching angles for a cascaded MLI, which eliminates specified higher order harmonics while maintaining the required fundamental voltage. This technique can be applied to MLIs with any number of levels. As an example, a seven-level inverter is considered and the optimum switching angles are calculated offline to eliminate the fifth and seventh harmonics (BurakOzpineci, Leon M. Tolbert, and John N. Chiasson, 2005). A.K.Al-Othman*et al.*have presented a method for output voltage harmonic elimination and voltage control in a PWM ac-ac voltage converter using the principle of hybrid Real-Coded Genetic Algorithm-Pattern Search (RGA-PS). RGA is the primary optimizer exploiting its global search capabilities, PS is then employed to fine tune the best solution provided by RGA in each evolution. The method enables linear control of the fundamental component of the output voltage and complete elimination of its harmonic contents up to a specified order. Theoretical studies have been carried out to show the effectiveness and robustness of the proposed method of SHE(A. K. Al-Othman, Nabil A. Ahmed, A. M. Al-Kandari, and H. K. Ebraheem ,2007).P.G.Song*et al.* have presented an eleven level cascaded converter as an application for high-power and/or high-voltage Hybrid Electric Vehicles (HEVs). GA optimization technique is applied to MLI to determine optimum switching angles for minimizing some predominant lower order harmonics via a cost function while maintaining the required fundamental voltage. By a MATLAB program, the optimum switching angles are calculated offline to weaken the 5^{th}, 7^{th}, 11^{th} and

13^{th} harmonics to less than 0.5% (P. G. Song, E. Y. Guan, L. Zhao, S. P. Liu, 2006). In 2005, Mohamed S. A. Dahidah, *et al.* have coined an optimal solution for eliminating pre-specified order of harmonics from a stepped waveform of a multilevel cascaded inverter topology with non-equal dc sources. An efficient hybrid real coded genetic algorithm (HRCGA) that reduces significantly the computational burden and results in fast convergence, is employed (Mohamed S. A. Dahidah and Vassilios G. Agelidis, 2005).A GA based selective principal component neural network method for fault diagnosis system in a MLI has been designed Leon M. Tolbert, *et al*. Principal component analysis (PCA) is utilized to reduce the neural network (NN) input size. The comparison among MLP neural network, principal component neural network (PC-NN), and GA based selective principal component neural network (PC-GA-NN) is performed (SurinKhomfoi, and Leon M. Tolbert, 2007).

Form the literature survey, it is inferred that GA is available for performing SHE technique more efficiently than the traditional algorithms. But in most of these publications it is assumed that the input dc sources for the MLI do not varies with time. This paper focus on the SHE technique applied to a 3-phase 7-level cascaded H-bridge multi-level inverter with both equal and unequal dc sources. The proposed method is based GA, which is suitable for all the MLI topologies and any number of output levels. The output voltage waveform, Fourier evaluation of switching angle calculation, n^{th} harmonic output equation and the algorithm for optimization of switching angles with equal and unequal dc sources are presented. The simulation study performed in Mat lab/Simulink gives many useful results.

II. SEVEN-LEVEL CASCADED H-BRIDGE INVERTER

The cascaded MLI consists of a series of H-bridge (single-phase full-bridge) inverter units. The general function of the MLI is to synthesize a desired voltage from several separate dc sources (SDCSs), which may be obtained from batteries, fuel cells, solar cells, and ultra-capacitors. Minimum harmonic distortion can be obtained by controlling the conducting angles at different inverter level. The seven-level cascaded inverter is shown in Figure.1.Each SDCS is connected to a single-phase full-bridge inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output side by different combinations of the four switches, S_1, S_2, S_3, and S_4. The ac output of each full-bridge inverter is connected in series such that the synthesized voltage waveform is the sum of all of the individual inverter outputs.

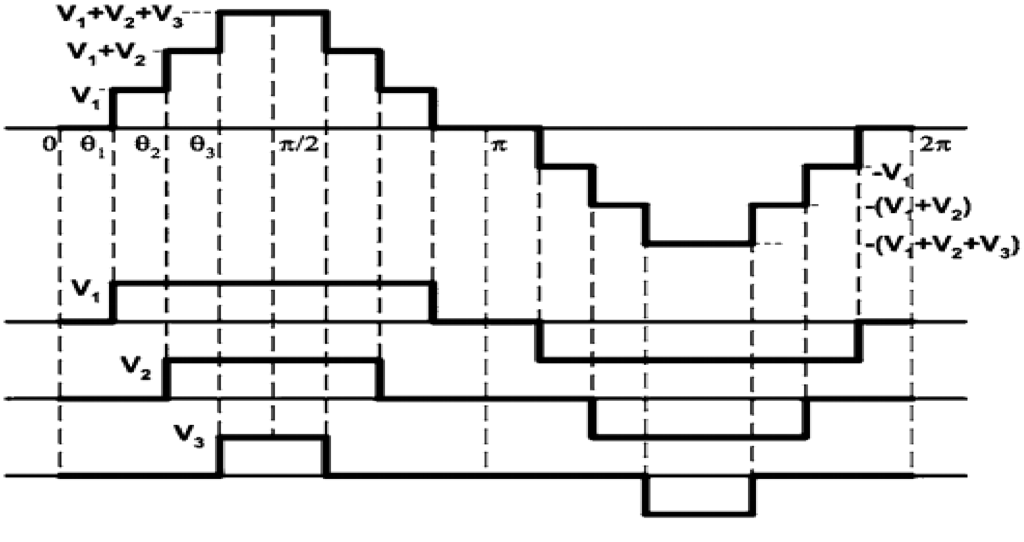


Figureure 1. Seven-level cascaded multilevel inverter

3. SELECTIVE HARMONIC ELIMINATION IN MULTILEVEL INVERTER

3.1 The Fourier Analysis

Consider the typical output waveform of the seven level cascaded MLI as shown in Figure.2. It does have the dc component and the even harmonics (because of odd quarter-wave symmetry).



Figureure 2. Output waveform-Seven-level cascaded MLI

By applying Fourier series to the above waveform, the output voltage is given by,

$$V_0 = a_0 + \sum_{n=1}^{\infty} a_n \sin(n\omega t) + b_n \cos(n\omega t) \quad (1)$$

$$A_n = \frac{2}{T}\int_0^T V_{dc} \sin(n\omega t) d(\omega t) \quad (2)$$

$$a_n = \frac{4}{\pi}\int_0^{\pi/2} V_{dc} \sin(n\omega t) d(\omega t)$$

$$b_n = 0, \text{for all values of 'n'} \quad (3)$$

For all ‘n’, from equations (1) and (2), the Fourier series is given as

$$V_0 = \sum_{n=1}^{\infty} a_n \sin(n\omega t) \quad (4)$$

For the waveform shown in Figure.2, the equation of ‘a_n’ is evaluated as follows,

$$a_n = \frac{4}{\pi}\left[\int_0^{\alpha_1} V_1 \sin(n\omega t)d(\omega t) + \int_{\alpha_1}^{\alpha_2} V_2 \sin(n\omega t)d(\omega t) + \int_{\alpha_2}^{\alpha_3} V_3 \sin(n\omega t)d(\omega t)\right] \quad (5)$$

$$a_n = \frac{4}{n\pi}[V_1\cos(n\alpha_1) + V_2\cos(n\alpha_2) + V_3\cos(n\alpha_3)] \quad (6)$$

The output voltage of the seven-level MLI waveform shown in Figure. 2 is expressed as,

$$V_0 = \sum_{n=1}^{\infty}\left[\frac{4}{n\pi}[V_1\cos(n\alpha_1) + V_2\cos(n\alpha_2) + V_3\cos(n\alpha_3)]\right] \quad (7)$$

When the input dc sources of the MLI are equal, that is if $V_1 = V_2 = V_3 = V_{dc}$, then equation (7) becomes,

$$V_0 = \sum_{n=1}^{\infty}\left[\frac{4*V_{dc}}{n\pi}[\cos(n\alpha_1) + \cos(n\alpha_2) + \cos(n\alpha_3)]\right] \quad (8)$$

Where, α_1, α_2 and α_3 are the inverter switching angles with the condition $\alpha_1 < \alpha_2 < \alpha_3 < \pi/2$, ‘n’ is the odd number. From equations (7) and (8), the amplitudes of the fundamental and odd-harmonic component of the output voltage are calculated. The lowest order harmonics are dominant and need to be eliminated from the inverter output voltage waveform. The inverter switching angles are optimized such that the lowest order harmonics are eliminated.

The fundamental amplitude of an inverter output voltage waveform is controlled using the modulation index given in equation (9). For a three-phase system the lowest non- triplen harmonics are need to be eliminated from the phase voltage. For three-level inverter, three angles (α1, α2, α3) are used to control the fundamental and eliminate the two lowest order harmonics such as 5^{th} and 7^{th}.

The Modulation Index for equal dc sources, $MI = \frac{V_f}{s*V_{dc}}$ (9)

The Modulation Index for unequal dc sources, $MI = \frac{V_f}{V_1+V_2+V_3}$ (10)

Where’s’ is the number of dc sources, V_1, V_2, V_3 are the individual dc sources, V_f-is the output fundamental voltage.

The fitness function for solving SHE equation using GA when the DC voltage sources are equal are given as,

$$\cos(\alpha_1) + \cos(\alpha_2) + \cos(\alpha_3) = M * s * \frac{\pi}{4}$$

$$\cos(5*\alpha_1) + \cos(5*\alpha_2) + \cos(5*\alpha_3) = 0$$

$$\cos(7*\alpha_1) + \cos(7*\alpha_2) + \cos(7*\alpha_3) = 0 \quad (11)$$

Equation (11) represents the non-linear transcendental equations for 3-phase 7-level inverter with equal dc sources for three switching angles per quarter cycle.

The fitness function for solving SHE equation using GA when the DC voltage sources are unequal are given as,

$$V_1 * \cos(\alpha_1) + V_2 * \cos(\alpha_2) + V_3 * \cos(\alpha_3) = V_f * \frac{\pi}{4}$$

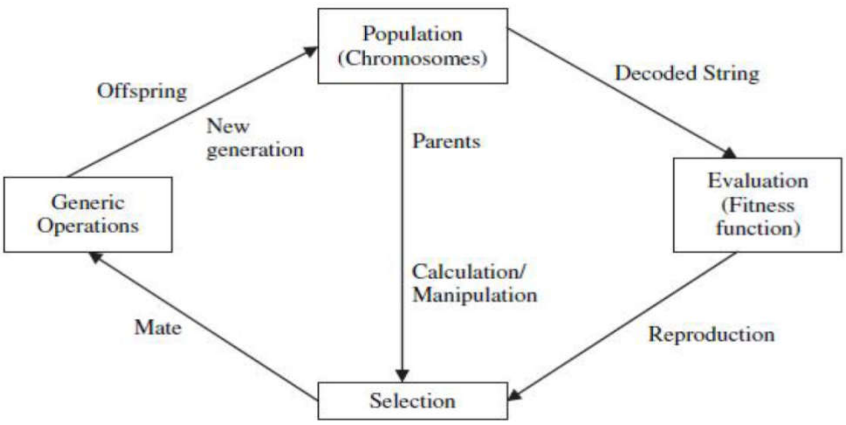
$$V_1 * \cos(5 * \alpha_1) + V_2 * \cos(5 * \alpha_2) + V_3 * \cos(5 * \alpha_3) = 0$$

$$V_1 * \cos(7 * \alpha_1) + V_2 * \cos(7 * \alpha_2) + V_3 * \cos(7 * \alpha_3) = 0(12)$$

Equation (12) represents the non-linear transcendental equations for 3-phase 7-level inverter with unequal dc sources for three switching angles per quarter cycle.The angles calculated by solving equations (11) and (12) have control over both the fundamental and also the selected lower order harmonics are to be eliminated.

3.2 Genetic Algorithm (GA)

Early research in optimization paved the different algorithms like artificial neural networks; Ant colony, Particle swarm optimization, bacterial foraging, etc were inspired by nature. GA is one such powerful algorithm which works by simulating evolution, starting from an initial set of solutions or hypotheses, and generating successive “generations" of solutions. This particular branch of artificial intelligence was inspired by the way living things evolved into more successful organisms in nature. The main idea is survival of the fittest, a.k.a. natural selection. Chromosomes have hereditary factors that determine particular traits of an individual are strung along the length of these chromosomes. Like an alphabet in a language, meaningful combinations of the bases produce specific instructions to the cell. The evolutionary process of a GA is a highly simplified and stylized simulation of the biological version. It starts from a population of individuals randomly generated according to some probability distribution, usually uniform and updates this population in steps called generations. Each generation, multiple individuals are randomly selected from the current population based upon some application of fitness, bred using crossover, and modified through mutation to form a new population.



Figureure.3 Genetic algorithm cycle

• **Crossover –** exchange of genetic material (substrings) occurred during reproduction and the chromosomes from parents exchange randomly. Therefore, the offspring exhibit some traits of the father and some traits of the mother.
• **Selection –** the application of the fitness criterion to choose which individuals from a population will go on to reproduce.
• **Replication –** the propagation of individuals from one generation to the next.
• **Mutation –** the modification of chromosomes for single individuals.

3.3 Genetic Algorithm toolbox Implementation Using MATLAB

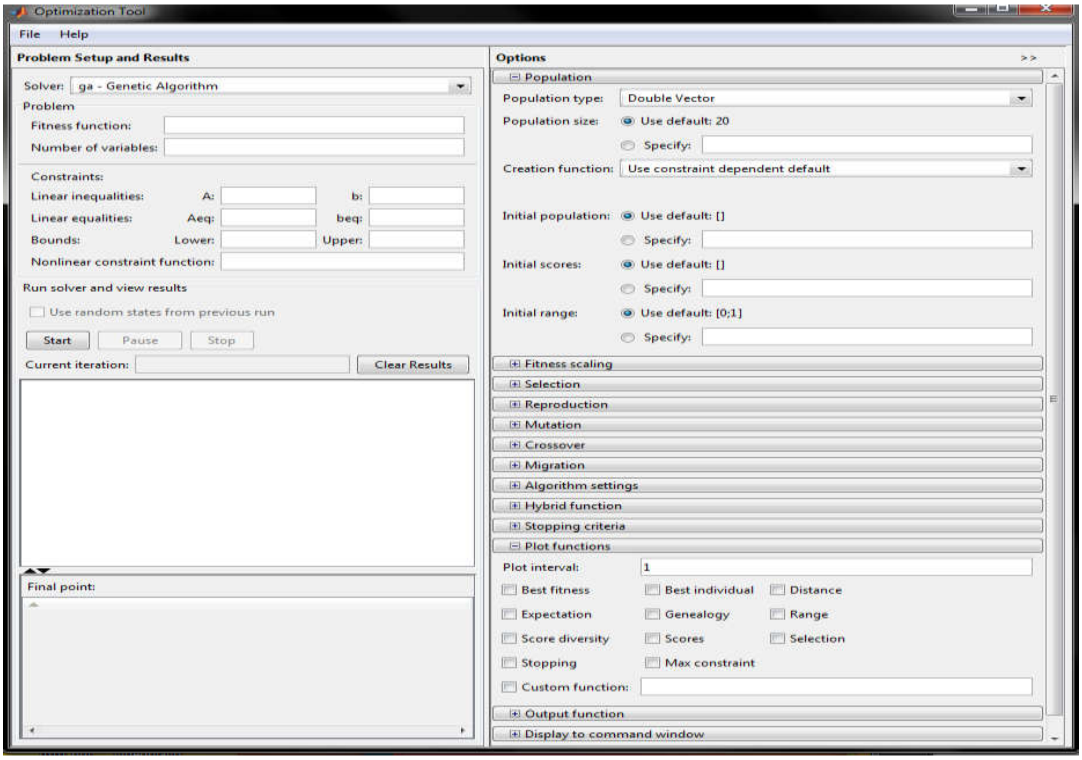
The Genetic Algorithm Toolbox uses MATLAB matrix functions to build a set of versatile tools for implementing a wide range of GA methods. The GA Toolbox is a collection of routines, written mostly in m-files, which implement the most important functions in genetic algorithms.

The GA Toolbox is a collection of functions that extend the capabilities of the Optimization Toolbox and the MATLAB numeric computing environment. The GA Toolbox includes routines for solving optimization problems using GA. These algorithms enable to solve a variety of optimization problems that lie outside the scope of the Optimization Toolbox. Toolboxes are set of standard library functions, which consist of predefined algorithms. The GA uses three main types of rules: selection, crossover and mutation at each step to create the next generation from the current population

The GA Tool is a graphical user interface that enables to use the GA without working at the command line. To open the GA Tool, enter "***gatool***"at the MATLAB command prompt. This opens the tool as shown in the Figure.4. To use Genetic Algorithm Tool the following information is needed,

Fitness function: It is the objective or fitness function to be minimized. In this paper equation 11 and 12 are taken as the fitness function for equal and unequal dc sources respectively. Enter the fitness function in the form @fitness fun, where fitness fun. m is an M-file that computes the fitness function.

Number of variables: The number of independent variables required for the fitness function is the number of switching angles to be calculated. Since a 3-phase 7-level inverter is taken in this paper, the number of switching angles to be calculated is three.



Figureure.4: Genetic Algorithm Toolbox

Linear inequalities: It is the form $A*x \leq b$ is specified by the matrix A and the vector b. The constraint in SHE technique is given as: $0 < \alpha_1 < \alpha_2 < \alpha_3 < \pi/2$.

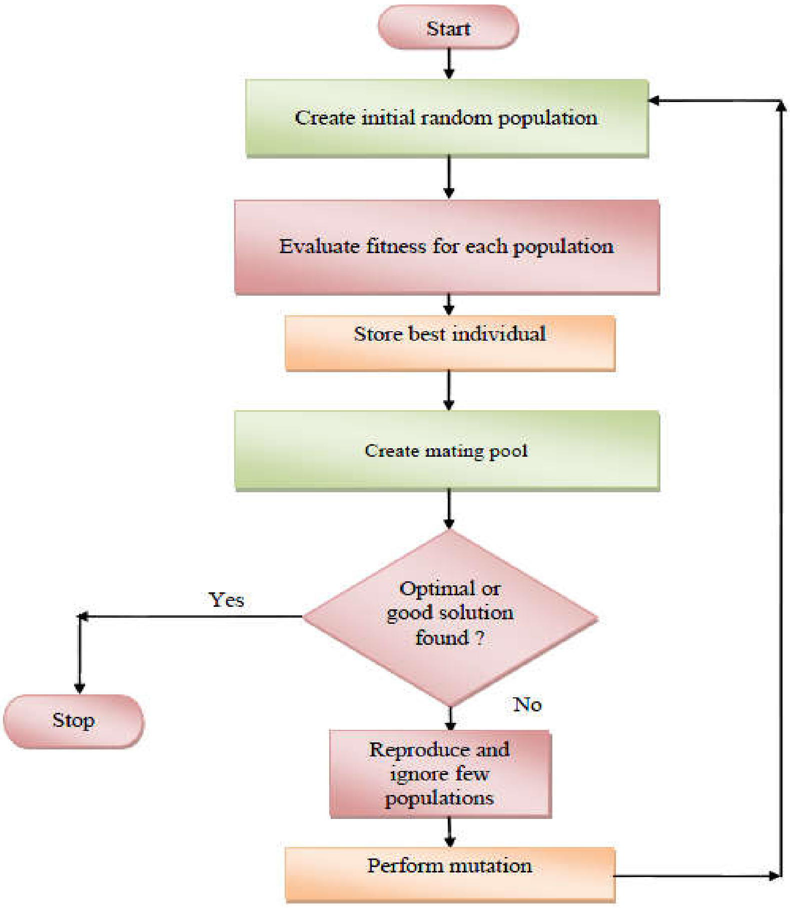
Therefore $\alpha_1 - \alpha_2 < 0$ and $\alpha_2 - \alpha_3 < 0$

$$A = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \end{bmatrix} B = [0 \quad 0]$$

Bounds: There are lower and upper bounds on the variables.

$\text{Lower bound} = [0 \;\; 0 \;\; 0]\text{andUpper bound} = [\pi/2 \, \pi/2 \, \pi/2]$

3.4 Flowchart for Genetic Algorithm (GA)



Figureure.5 Flowchart of Genetic Algorithm

Figure.5 dictates the algorithmic steps involved in the GA based SHEPWM techniques to eliminate selected lower order harmonics (5^{th} and 7^{th}) in the output voltage waveform for different modulation index with equal and unequal dc sources. The first step is creating initial population of parameters to be optimized. Then the fitness of each individual is computed and best individuals are retained. The objective function value is computed and checked for optimal solution. If the solution is not optimal, the reproduction is done after elimination of few populations. Now, operators such as "crossover" and "mutation" are used to get the populations for next iteration.

IV. SIMULATION EVOLUTION

The 3-phase 7-level inverter with constant 50V dc input of each bridge is simulated in MATLAB/Simulink platform. Figure.6 shows the phase voltage and its harmonic spectrum for un-optimized switching angles. The switching angles are taken randomly as $\alpha_1=30^0$; $\alpha_2=60^0$; $\alpha_3=90^0$.

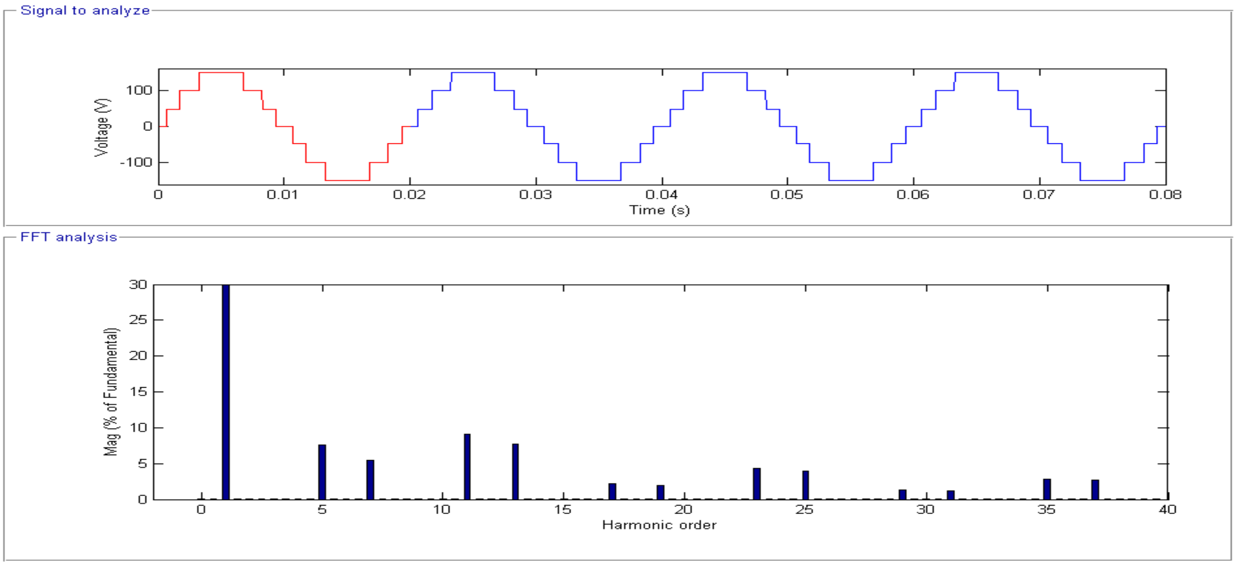


Figure.6. Output RY-line voltage and harmonic spectrum -without optimization

The result shows that the lower order harmonics viz. 3rd, 5th, 7th and 11th harmonics are dominant. The values of lower order harmonics: V_5=5.36%, V_7=3.58%, V_{11}=9.09%, V_{13}=7.69%, V_{17}=1.57%.Since it is a 3-phase MLI, the 3rd harmonics are eliminated in the line voltage and even harmonics are absent due to quarter wave symmetry. Thus in this paper the 5th and 7thharmonics are considered for elimination.

4.1 GA simulation results with equal dc sources

For input dc voltages, $V_1= V_2= V_3=V_{dc}$ = 50V, the switching angles are optimized using GA and tabulated for different modulation index in Table 1. For the range of MI studied, 5th and 7thharmonics are reduced to almost negligible values. The THD decreases with increase in MI like any other PWM methods. The representative harmonic spectrum is presented for MI=0.8 in Figure.7.The THD values of output voltage for a range of MI is indicated in Figure.8 and the variation of switching angles are presented in Figure.9. The linear relation between MI and the fundamental voltage component is substantiated in Figure.10.

Table 1. GA Optimized switching angles equal input sources

MI	Firing Angles (degree)			Fundamental Voltage (V)		THD (%)	V_5 (%)	V_7 (%)
	α_1	α_2	α_3	Theoretical	Simulated			
0.40	46.33	83.76	88.78	60.0	50.82	63.82	0.81	1.12
0.45	40.91	65.54	88.94	67.5	74.32	49.66	1.2	0.14
0.50	40.23	64.11	88.21	75	77.07	48.93	0.64	0.04
0.55	39.80	62.37	86.78	82.5	80.71	48.85	0.67	0.08
0.60	39.50	58.60	83.03	90	88.83	48.67	0.74	0.02
0.65	39.39	55.61	79.05	97.5	96.13	47.97	0.57	0.03
0.70	18.96	52.33	87.36	105	100.5	23.43	0.03	0.27
0.75	15.05	46.05	85.44	112.5	109.2	20.54	0.12	0.08
0.80	12.78	42.85	85.55	120	119.2	19.11	0.35	0.07
0.85	20.46	46.87	64.62	127.5	129.2	25.88	0.13	0.31
0.90	16.32	41.34	63.70	135	135.9	20.02	0.07	0.08
0.95	13.10	35.73	61.22	142.5	143.1	15.57	0.15	0.03
1.00	12.68	23.32	54.18	150	156.8	13.43	0.03	0.03
1.20	11.70	12.30	36.83	180	174	20.16	0.15	0.05

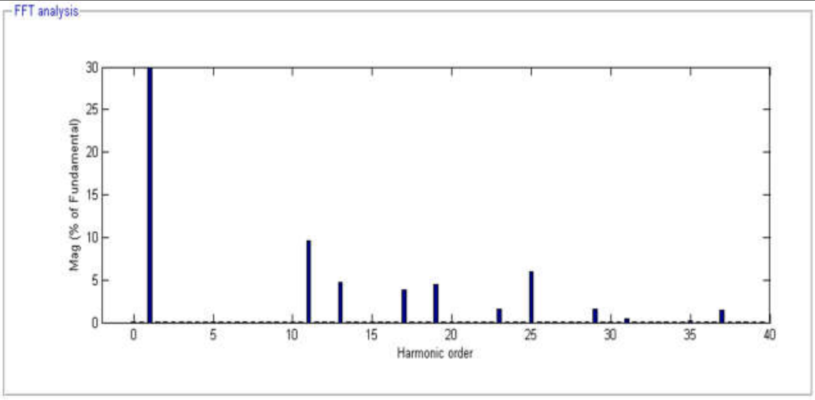


Figure.7: Harmonic spectrum with equal dc sources for MI=0.8

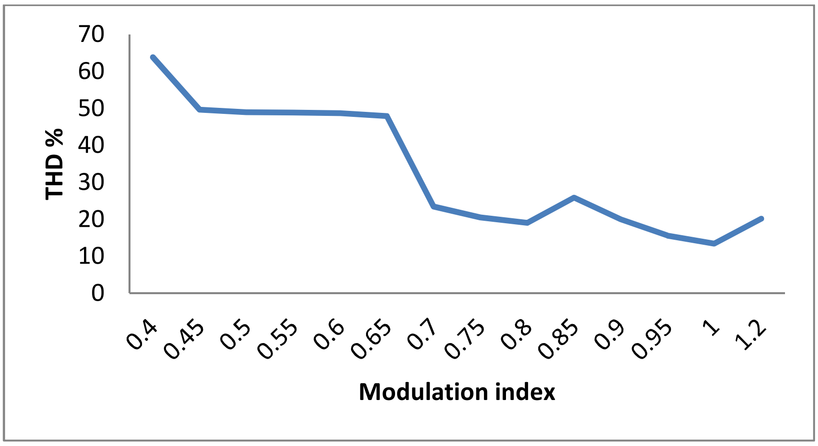


Figure.8. MI versus THD for equal voltage sources

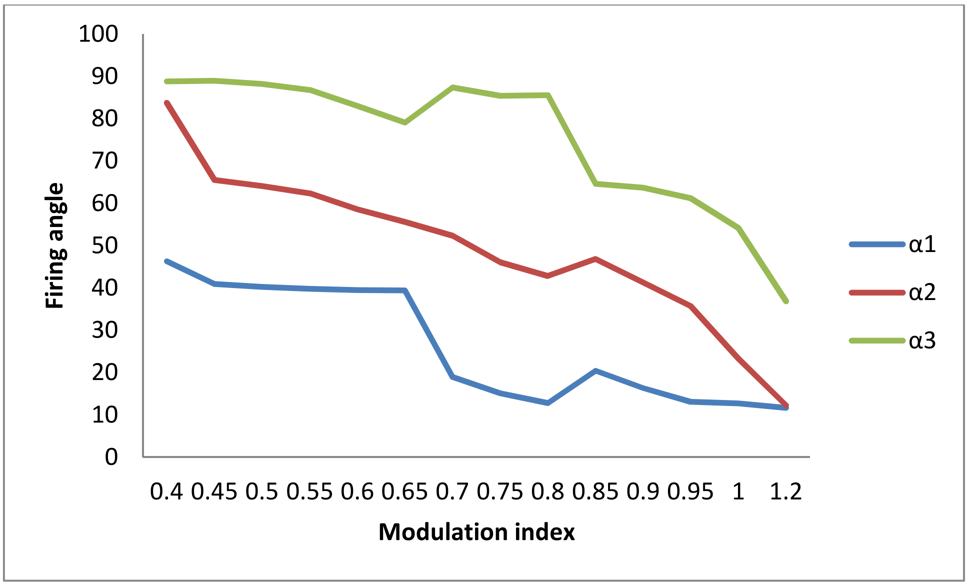


Figure.9. Switching angles for various modulation indices –Equal sources

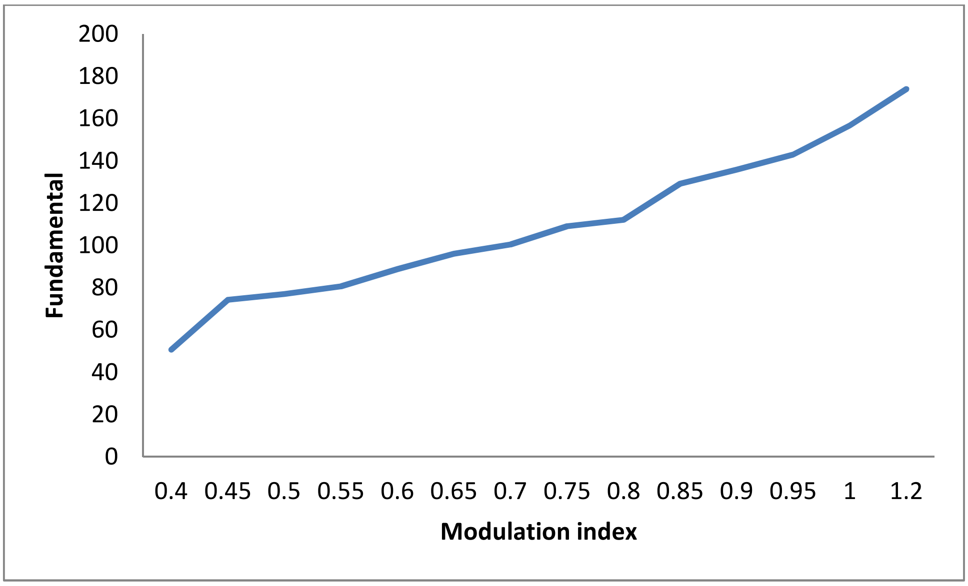


Figure.10: Fundamental voltages for various modulation indices-Equal sources

4.2 GA simulation results with unequal dc sources

Undoubtedly, a host of SHEPWM methods are viable for MLIs working with equal dc sources. However, in practical cases the separate dc sources do not have equal voltage levels. Also, there are suggestions to optimize the voltage levels V_1, V_2 and V_3, to improve the distortion level (Qin Jiang, Thomas A. Lipo, 2000). It is worthwhile to note that for any modulation index, the switching angle solved for equal voltage sources may not work well for unequal voltages. For instance, the optimized switching angle for at MI=0.8 considered for equal voltage sources (Figure.7) may not work well for unequal voltage sources. When the same switching angles are used for the unequal input dc voltages, the harmonic spectrum, Figure.11, shows undisputable appearance of 5^{th} and 7^{th} components. The optimum dc values are obtained using theory of resultant as V_1= 60 V; V_2=47V; V_3= 43V (L.M. Tolbert, J.N. Chiasson, D. Thong, KJl. McKenzie, 2005).

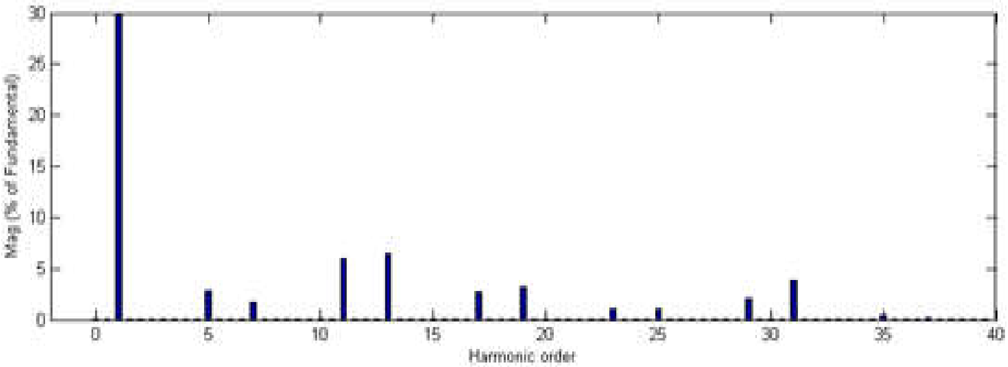


Figure.11 Failure of switching angles optimized for equal sources in unequal sources

The optimization must be performed separately when unequal sources are used (F. J. T. Filho, T. H. A. Mateus, H. Z. Maia, B. Ozpineci, J. O. P. Pinto and L. M. Tolbert ,2008, H. Taghizadeh and M. TarafdarHagh ,2010*)*. Such a solution using the fitness function of unequal sources is presented in Table 2. A representative harmonic spectrum is presented for MI=0.8 in Figure.12. The variation of optimized switching angles with the modulation index is pictured in Figure.13. The variation THD with respect to MI is curved in Figure.14. It is proved from the Figure.15 that the linearity between fundamental component and the modulation index does not disturbed by the GA based optimization even when unequal dc sources are assumed. Tables 3 and 4 demonstrate the results for elimination of either 5^{th} and 7^{th} or 7^{th} and 11^{th}. The values of un-eliminated lower order harmonics and THD are also added for study. The improvement in THD values due to the application of SHE is commendable in unequal sources. The THD value of unequal dc sources is worsened when switching angles optimized for equal voltages are used.

Table 2: Switching angles by GA for unequal voltages

MI	Firing Angle (Degree)			Fundamental Voltage(V)		THD (%)	V_5 (%)	V_7 (%)
	α_1	α_2	α_3	Theoretical	Simulated			
0.40	46.54	84.43	86.08	60	60.71	64.4	0.63	0.54
0.45	45.21	89.79	75.69	67.5	66.21	53.85	0.68	0.51
0.50	43.57	70.79	89.83	75	73.85	51.13	0.69	0.36
0.55	42.28	66.68	87.54	82.5	81.26	50.05	0.66	0.22
0.60	41.23	62.00	83.25	90	90.76	48.9	0.68	0.04
0.65	40.67	59.70	80.11	97.5	96.36	47.97	0.59	0.11
0.70	19.12	55.43	90.00	105	104.5	19.92	0.06	0.27
0.75	17.65	51.11	87.33	112.5	111.3	19.59	0.03	0.24
0.80	12.60	41.67	86.25	120	121.3	17.35	0.31	0.02
0.85	8.69	33.90	89.24	127.5	124.4	19.58	0.34	0.18
0.90	19.60	47.73	63.98	135	135	21.73	0.07	0.22
0.95	15.24	40.05	62.59	142.5	143.5	15.47	0.21	0.08
1.00	12.95	34.80	59.93	150	149.8	12.48	0.16	0.03
1.20	1.82	21.96	35.33	180	175.6	19.21	0.3	0.28

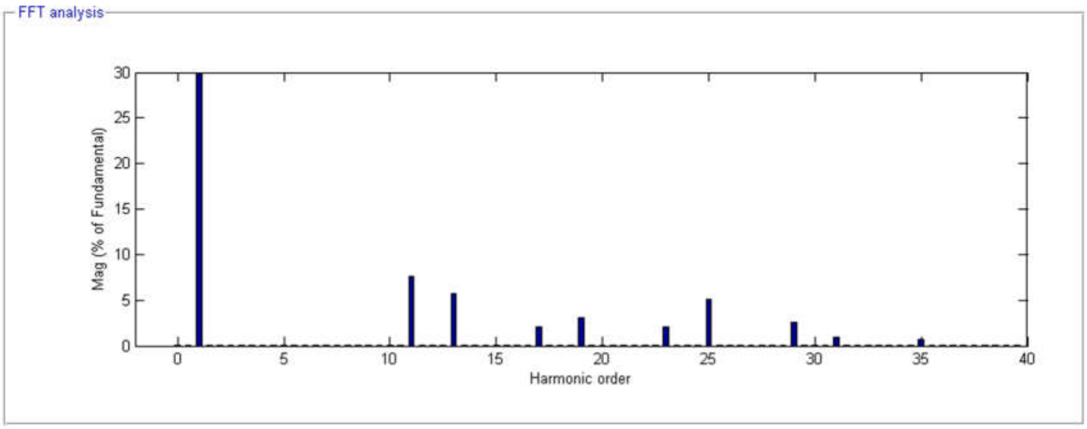


Figure.12 Harmonic spectrum for unequal dc sources- MI = 0.8

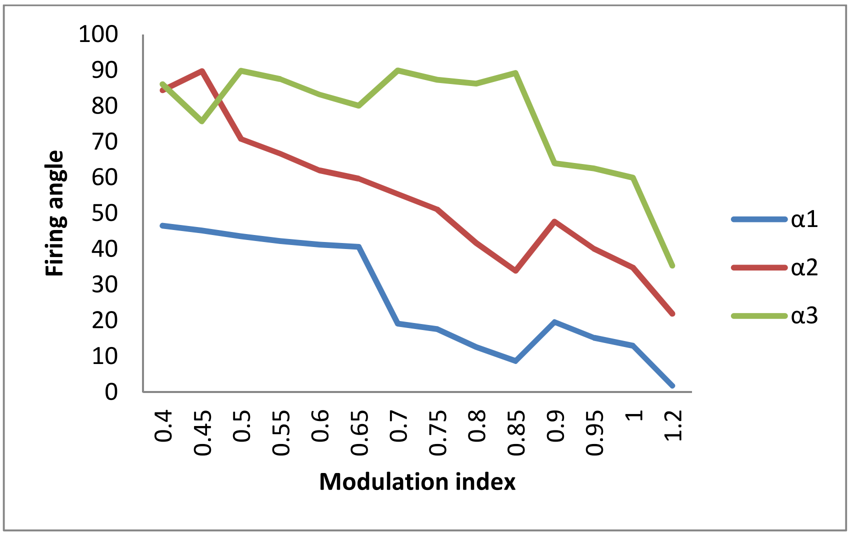


Figure.13Switching angles for various modulation indices-unequal sources

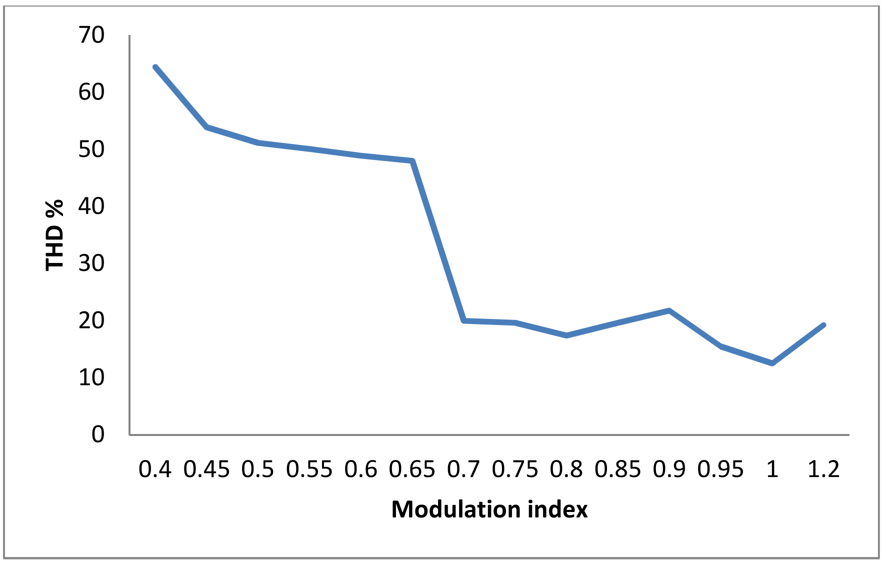


Figure.14 THD values for various modulation indices -unequal sources

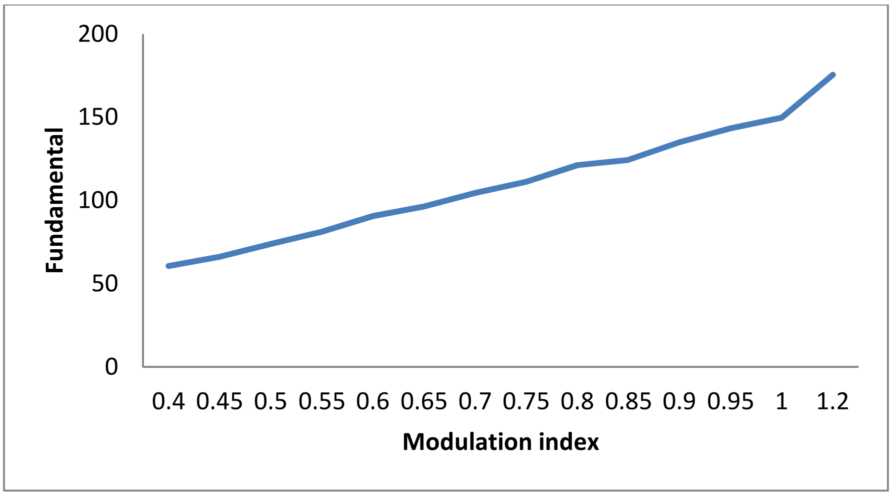


Figure.15 Fundamental voltages for various modulation indices -unequal sources

Table 3: Comparison of GA results at MI=0.8-equal voltage

Switching Angles	V_1(V)	V_5(%)	V_7(%)	V_{11}(%)	V_{13}(%)	THD (%)
Un-optimized	85.47	4.92	3.52	9.09	7.69	32.48
For elimination of 5^{th}& 7^{th}	119.20	0.33	0.07	9.68	4.58	19.11
For elimination of 7^{th}& 11^{th}	121.40	6.48	0.31	0.13	2.17	17.12

Table 4: Comparison of GA results at MI=0.8-unequal voltage

Switching Angle	V_1(V)	V_5(%)	V_7(%)	V_{11}(%)	V_{13}(%)	THD (%)
Un-optimized	94.57	7.18	5.14	9.09	7.69	29.82
Optimized for equal voltages	121.1	1.58	2.26	9.10	5.28	17.51
For elimination 5^{th} and 7^{th}	120	0.31	0.02	7.51	5.72	17.35
For elimination 7^{th} and 11^{th}	125.3	1.97	0.10	0.02	0.80	18.72

V. CONCLUSION

In this paper, a SHEPWM method for MLI working with unequal input dc voltage sources is presented. Simulation result shows that, Genetic Algorithm (GA) optimization toolbox is triumph in eliminating the selected lower order harmonics irrespective of the MI value. The well optimized SHEPWM results also in lower THD and increased fundamental voltage. The following major inferences are summarized.

(i) The un-optimized angles results in objectionable level of lower order harmonics and THD both for the equal and the unequal voltages

(ii) Even though the optimization guarantees the complete elimination of selected harmonics, the other lower order harmonics persist.

(iii) Irrespective of the orders of harmonics considered, the is a increased in the fundamental component and reduction in THD, and

(iv) The set of angles optimized for equal voltages may not work well for unequal voltages.

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