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Genetic Algorithm Based Active Front End RectifierControlling Scheme forMulti-cell Converters

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Abstract: Multi-cell converters permit the utilization of AC motor drives for medium and high voltage level applications utilizing low voltage semiconductors. This sort of converter has a multi-pulse transformer which performs the cancelation of the low frequency harmonics created by the three-phase diode rectifiers. However this point of preference, the multi-pulse transformer is bulky, costly, and depends upon power cells, making the transformer topology complex. This work proposes a genetic algorithm based switching approach to decrease the transformer related problemsin multi-cell converters. The evolutionary nature of proposed algorithm makes it flexible and can automatically evolve according to requirements provided by objective function.

Keywords: Genetically Controlled Rectifier, Multi Cell Rectifier, Power Quality Improvements, THD minimization.

I. Introduction

The utilization of multilevel converters has been expanding as of late in applications for AC drives, in light of the fact that some AC motors should be sustained with medium or high voltages. For these applications, an inverter with semiconductor devices with high blocking voltages could be utilized; however, the failure to produce a voltage waveform with both low THD and low dv/dt makes its utilization unconventional.

The multilevel converter rises as a distinct option for the two levels inverter. A topology that is broadly utilized for such converters is the cascaded H-bridge based converter, with symmetrical DC voltages, which incorporates a multi-pulse transformer and three-phase to single-phase power cells. Every power cell is framed by a three phase diode bridge rectifier, a DC voltage join, and a solitary phase voltage source inverter. The current of the three-phase rectifier has an undesirable high harmonic substance; in any case, utilizing a multi-pulse transformer, these harmonic parts are counteracted and in this way they are not reflected back to the source.

However all these methodologies require the utilization of a multi-pulse transformer, which is massive, costly, and must be designed according tothe number of power cellsused. Nonetheless, the utilization of genetically controlled rectifiers permit dealing with the active/reactive power and the DC voltage control. Theoptimization schemes that have been adopted for solving the complex mathematical problems in recent pastarebased on evolutionary algorithms. This is because of the way it deals with nol-linear systems and other constrains.The paper presents a control technique taking using genetic algorithm for controlling multi-cell converters. The method provides the good harmonic reduction and DC voltage controlling without need of complex multi-pulse transformers.The proposed method can be utilized at the power cell level or on complete converter.

2. Proposed Harmonic Reduction Technique

The proposed genetically controlled Active Front End rectifier system has the flexibility to operate with any system configuration or topology with fast convergence which makes this strategy suitable for the input rectifiers.

In particular, it is proposed the use of the topology shownin Fig. 1(a), which is composed of three-phase wye-to-wye transformers. Each secondary feeds an genetically controlled rectifier, which has a DC link capacitor to hold the voltage, and a resistive load is considered for simplicity. The input current reference template for each genetically controlled rectifier is required to emulate an 18pulses input current, where its fundamental component features a phase shift α however this angle can be made fixed to use the existing transformer because the genetic algorithm can be forced to search the switching pattern of rectifier for the given angle.

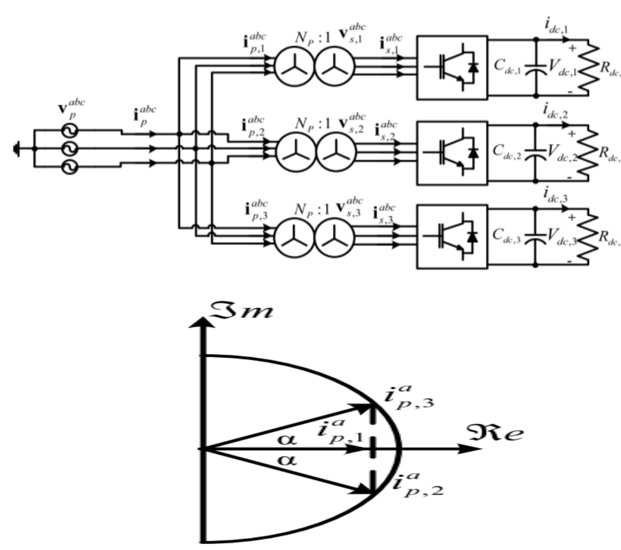

Figure 1. Topology and Harmonic minimization scheme; (a) multi-cell AFE rectifier with wye-wye transformers, (b) phasor diagram of the input currents for the AFE rectifiers.

The proposed THD minimization searches the switching pattern for each cell rectifier so that the output voltage of each cell remains equal to the required voltage, but the harmonics produced by each cell because of switching cancels out each other's when they summed after shifting their phase by angle α.

Considers the fundamental current components shown in Fig. 1(b), where the phase shift angle α is responsible for allowing the harmonic cancellation.

Thecurrents referred to the primary winding of the transformeris given by,

For rectifier 1:

$$i_a^1 = \frac{Icos(\alpha)}{N_p}[\sin(\omega t) - F(\sin(\omega t))], (1)$$

For rectifier 2:

$$i_a^2 = \frac{I}{N_p}[\sin(\omega t - \alpha) - F(\sin(\omega t - \alpha))], (2)$$

For rectifier 3:

$$i_a^3 = \frac{I}{N_p}[\sin(\omega t + \alpha) - F(\sin(\omega t + \alpha))], (3)$$

Where $F()$ is a function representing the harmonic distortion produces by the system.
Assuming that the transformer's turns ratio is unitary ($N_P = 1$), the overall input current for phase a is given by,

$$i_a^{all} = \frac{1}{N_p}\Big[\cos(\alpha)[\sin(\omega t) - F(\sin(\omega t))] + [\sin(\omega t - \alpha) - F(\sin(\omega t - \alpha))] + [\sin(\omega t + \alpha) - F(\sin(\omega t + \alpha))]\Big], \dots\dots\dots\dots\dots (4)$$

The equation (4) shows the waveform of the input current of the converter. Now to operate the converter properly with the drive the two things required to be controlled one is the power supplied to drive and second is to reduce the harmonic distortion.
As we can see in the equation (4) the harmonic distortion is caused by the terms $F()$ we used this function instead of other derived expressions because for many complex system it is difficult to completely express it by any equation.
Now according to our algorithm these two controlling is done by switching the rectifier such that it produces a discrete waveform shown in figure 2. Now putting this waveform into the equation (4) we can calculate the fundamental component and harmonic components of the input current using Fourier analysis.

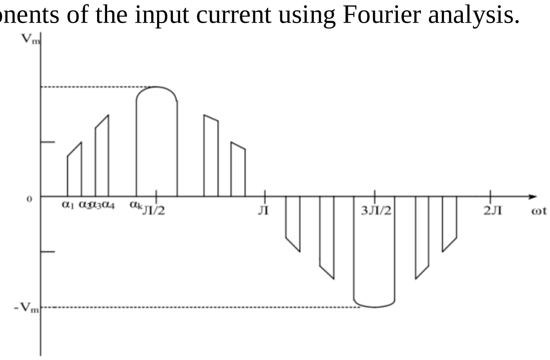

Figure 2. Discrete Input Current Waveform for Rectifier with genetically controlled switching.

The current can be expressed using Fourier series as

$$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos\omega t + \sum_{n=1}^{\infty} b_n \sin\omega t \dots. (5)$$

the coefficients a_n and a_0 are reduced to zero as the output voltage waveform is purely symmetrical. The above equation is thus reduced to

$$f(t) = \sum_{n=1}^{\infty} b_n \sin\omega t \dots\dots\dots (6)$$

Equation 2 needs to be evaluated only for odd values of n.

The value of b_n is computed as

$$b_{n,(n\neq1)} = \frac{2I_m}{\pi}\left[\frac{\sin(n-1)\,\omega t}{(n-1)} - \frac{\sin(n+1)\,\omega t}{(n+1)}\right]_{\alpha_1,\alpha_3,\dots\alpha_k}^{\alpha_2,\alpha_4,\dots\frac{\pi}{2}}, \dots (7)$$

Where I_m is the maximum value of the input sine wave. The fundamental component can be computed as

$$b_1 = \frac{2I_m}{\pi}\left[\omega t - \frac{\sin n\omega t}{2}\right]_{\alpha_1,\alpha_3,\dots\alpha_k}^{\alpha_2,\alpha_4,\dots\frac{\pi}{2}} \dots\dots (8)$$

The objective is to trace out the switching angles to make $b_1 = V_0$ and to perform selective harmonic elimination, where V_0 is the reference output voltage. For m number of switching pulses let $obj(\alpha)$ be the objective function then the optimization problem can be mathematically stated as

$$obj(\alpha) = obj(\alpha_1, \alpha_3, \dots\dots\dots.\alpha_k) = e_r + h_c, \dots (9)$$

Subject to

$$0 \le \alpha_1 \le \alpha_2 \dots\dots\dots. \le \alpha_{k-1} \le \alpha_k \le \pi/2$$

Where

$$e_r = \left|V_0^* - B_1/\sqrt{2}\right| \dots\dots\dots\dots\dots\dots\dots\dots (10)$$

$$h_c = |B_3| + |B_5| + |B_7| \dots\dots + |B_{k-1}| \dots\dots (11)$$

3. Genetic Algorithm

A genetic algorithm (GA) is a search heuristic that copies the procedure of common evolution. This heuristic is routinely used to create valuable solutions to optimization and search issues. Genetic algorithms have a place with the bigger class of evolutionary algorithms (EA), which create solutions to optimization issues utilizing procedures propelled by common evolution, for example, inheritance, mutation, selection, and crossover.

In a genetic algorithm, a populace of strings (called chromosomes or the genotype of the genome), which encode hopeful solutions (called people, animals, or phenotypes) to an

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optimization issue, advances toward better solutions. Generally, solutions are spoken to in paired as series of 0s and 1s, yet different encodings are additionally conceivable. The evolution for the most part begins from a populace of haphazardly produced people and happens in eras. In every era, the fitness of each person in the populace is assessed, multiple people are stochastically chosen from the current populace (in light of their fitness), and changed (recombined and conceivably arbitrarily transformed) to shape another populace. The new populace is then utilized as a part of the following emphasis of the algorithm. Generally, the algorithm ends when either a most extreme number of eras has been created, or a palatable fitness level has been gone after the populace. In the event that the algorithm has ended because of a greatest number of eras, an agreeable solution could conceivably have been come to.

Genetic algorithms discover application in bioinformatics, phylogenetics, computational science, building, financial aspects, science, fabricating, arithmetic, material science and different fields. An ordinary genetic algorithm requires:

•A genetic representation of the solution area,

•A fitness capacity to assess the solution area.

A standard representation of the solution is as a variety of bits. Varieties of different sorts and structures can be utilized as a part of basically the same way. The principle property that makes these genetic representations advantageous is that their parts are effortlessly adjusted because of their settled size, which encourages basic crossover operations. Variable length representations might likewise be utilized, yet crossover usage is more unpredictable for this situation. Tree-like representations are investigated in genetic programming and chart structure representations are investigated in evolutionary programming.

A representation of a solution may be a variety of bits, where every piece speaks to an alternate item, and the estimation of the bit (0 or 1) speaks to regardless of whether the article is in the backpack. Not each such representation is substantial, as the extent of articles might surpass the limit of the rucksack. The fitness of the solution is the total of estimations of all items in the rucksack if the representation is legitimate or 0 generally. In a few issues, it is hard or even difficult to characterize the fitness expression; in these cases, interactive genetic algorithms are utilized.

Once the genetic representation and the fitness capacity are characterized, a GA continues to instate a populace of solutions (generally haphazardly) and after that to enhance it through monotonous use of the mutation, crossover, reversal and selection administrators.

4. Simulation Results

The simulations for the proposed algorithm are performed for value for various combinations of input parameters and for various output requirements. All results are simulated using MATLABR2012b, on Windows 8 with Intel i3 processor and 4 GB of RAM.

Table 2: The GA configuration.

Variable Name	Variable Value
Population Size	32
Maximum Generation	100
Mutation Probability	0.05
Tolerance	0.01

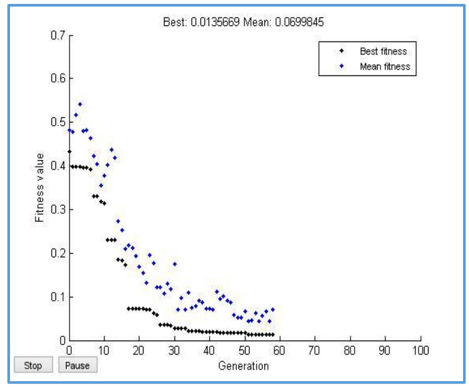

Figure 3: Convergence of the Genetic Algorithm.

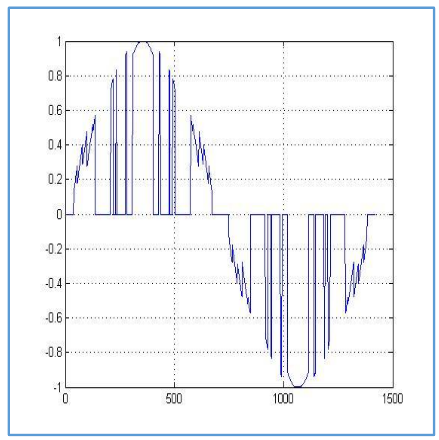

Figure 4: the waveform of current through single cell because of switching.

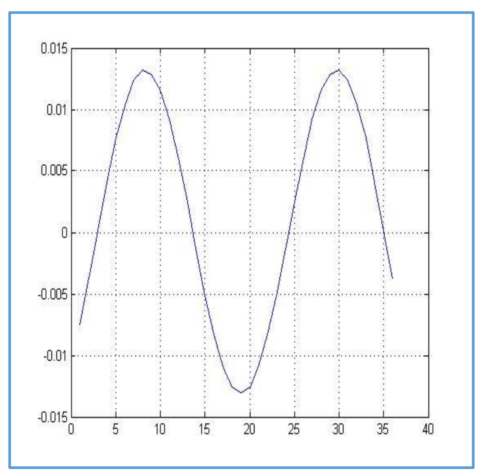

Figure 5: The waveform of input (sum of all cell) current through the converter.

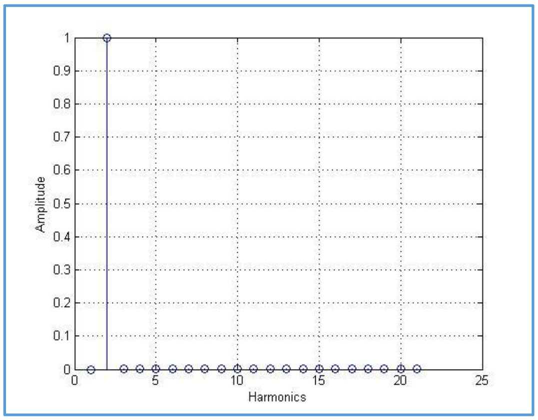

Figure 6: Amplitudes of different harmonics and fundamental component in linear Y axis scale (THD = 0.1932%).

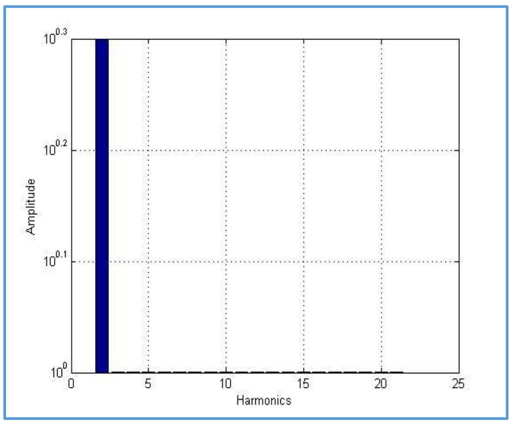

Figure 7: Amplitudes of different harmonics and fundamental component in Log Y axis scale (THD = 0.1932%).

5. Conclusion

The paper presented a new harmonic minimization strategy for a multi-cellgeneticallycontrolled AFErectifier. This minimization requires the off-line or online calculation of the input current references for the AFE rectifiers, which can accept any phase shift angle α for the transformer. The aim is to use a control technique instead of using complextransformer design for the harmonic minimization in converters, resulting in much simpler transformer design. To accomplish this, a genetic based approach is used to simultaneously control the input current and theDC voltage regulation of each power cell. Simulated results verifies the better performance of the proposed scheme as it can achieves the THD as low as 0.19%.

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