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Selective Harmonic Elimination in a Multilevel Inverter Using Grasshopper Optimisation

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ABSTRACT: This project investigates the application of the Grasshopper Optimization Algorithm (GOA), a bio-inspired algorithm, for optimizing switching angles in a three-phase cascaded H-bridge multilevel inverter. The GOA aims to generate switching angles that produce an output voltage waveform with a desired fundamental component while minimizing the presence of unwanted 5th and 7th order harmonics. Simulation results suggest that the GOA achieves a wider modulation index range compared to the Newton-Raphson technique and offers superior performance in minimizing the objective function when compared to Genetic Algorithms. Furthermore, this project proposes the design and simulation of a multi-level inverter employing Selective Harmonic Elimination (SHE) techniques. The system leverages switching strategies to generate a high-quality, low-distortion AC output. The fundamental objective is to demonstrate the significant reduction in harmonic content achievable with the proposed SHE-based cascaded H-bridge multi-level inverter utilizing grasshopper optimization, compared to conventional multi-level inverter designs.

KEYWORDS: Three-phase system, Cascaded H-bridge inverter, 5-level inverter, 7-level inverter, Harmonic reduction, Minimized specific harmonics, Switching angle optimization, Wider modulation index range, Improved objective function minimization

I. INTRODUCTION

Power electronic converters are devices that alter the form of electrical energy. In many different applications, such as power systems, industrial operations, renewable energy systems, electric automobiles, and consumer electronics, they play a significant part in managing and controlling electrical power. These converters are capable of carrying out a variety of tasks, including switching an electrical power's voltage or frequency and regulating the magnitude or waveform of its current or voltage. They can also convert an electrical power from AC to DC or vice versa. Between the power source and the power supply output, the converter serves as a conduit. By providing currents and voltage in the form required for the end-user loads, it works to process and regulate the flow of electric energy. Depending on the application, converters can be as simple as a transformer or more complicated.

Harmonics in power electronics refer to the presence of unwanted frequency components in the electrical power system. These harmonics are typically caused by the operation of power electronic devices and can have various detrimental effects on the power system. Harmonics can also be defined as the voltages or currents with frequencies that are integer multiples of the fundamental power frequency. For example, if the fundamental frequency is 50Hz, then the second will be of 100Hz, third will be of 150Hz and it keeps going on.

A three-level inverter and a multilevel inverter are both types of power electronic converters used to convert DC to AC. However, there are some key differences between these two types of inverters. First and foremost the key difference will be the number of voltage levels produces as a ideal three level inverter is capable of producing only three voltage levels, whereas multilevel inverters are capable of producing more than three levels. The second argument is that the waveform quality of a multilevel inverter is much better than that of a three-level inverter. Because of this it has better power quality and lower THD. The three level inverter has a much simpler circuit configuration compared to multilevel inverters. The circuit complexity increases with the number of voltage levels, making multilevel inverters more complex to design and implement. The voltage stress on the power semiconductor devices in a three-level inverter is moderate compared to multilevel inverters. This can result in better device reliability and higher overall efficiency but in comparison with Multilevel inverters distribute the voltage stress across multiple devices, reducing the voltage rating

required for individual devices. This can improve the reliability and efficiency of the inverter, particularly in high-power applications. Three-level inverters are suitable for a wide range of applications, including motor drives, renewable energy systems, and grid-tied inverters. They offer a balance between complexity, cost, and performance. Multilevel inverters find applications in high-power systems, such as high-voltage transmission systems, electric vehicle charging stations, and large-scale renewable energy installations. They are particularly beneficial when high-voltage operation, reduced harmonics, or improved power quality is required.

II. RELATED WORK

Prior research has established SHE as a successful approach for minimizing specific harmonics in the output voltage of multilevel inverters. Particle Swarm Optimization (PSO) and Genetic Algorithms (GA) have been employed for SHE, demonstrating their effectiveness in achieving the desired fundamental component while suppressing targeted harmonics. However, these algorithms can face challenges related to convergence speed and getting trapped in local optima. This project introduces the Grasshopper Optimization Algorithm (GOA) as an alternative for SHE in multilevel inverters. Unlike PSO and GA, GOA mimics the foraging behavior of grasshoppers, potentially offering advantages in terms of exploration and exploitation capabilities during the optimization process. The following sections will detail the application of GOA for SHE in a three-phase cascaded H-bridge multilevel inverter and compare its performance with existing techniques. This project contributes to this ongoing research by thoroughly evaluating the effectiveness of GOA for SHE in a three-phase cascaded H-bridge multilevel inverter. The performance of the proposed GOA-based SHE approach will be compared with established techniques, such as Newton-Raphson and PSO, through simulations and potentially hardware implementation. The results will be presented and discussed, aiming to provide valuable insights into the potential of GOA for SHE in multilevel inverter applications.

III. METHODOLOGY

Selective Harmonic Elimination (SHE) is a technique used to eliminate specific harmonic frequencies in the output waveform of power electronic converters. Harmonics are unwanted sinusoidal components that are multiples of the fundamental frequency in a power system. They can cause issues such as increased losses, distortion, and interference with other equipment. The process of selective harmonic elimination involves solving a set of nonlinear equations to determine the switching angles and pulse widths that will eliminate the desired harmonics.

These equations are derived from the Fourier series representation of the converter output waveform, where the coefficients of the harmonics are set to zero to achieve elimination. There are various methods and algorithms available to solve the nonlinear equations involved in selective harmonic elimination, including iterative techniques, optimization algorithms, and numerical methods. Some commonly used methods include the Newton-Raphson method, particle swarm optimization, and genetic algorithms. In our case we are going to use Grasshopper algorithm used with a cascaded H-bridge Multilevel inverter. Grasshopper optimization algorithm (GOA) is a nature-inspired algorithm developed based on the swarm behavior of grasshoppers in nature. The algorithm mimics the behavior and movement of grasshoppers in an attempt to solve optimization problems. In GOA, the movement of a grasshopper in the search region is influenced by the social forces between the grasshopper and the entire grasshopper population. The social forces are repulsion force for exploring the search regions globally and attraction force for exploiting the promising regions locally.

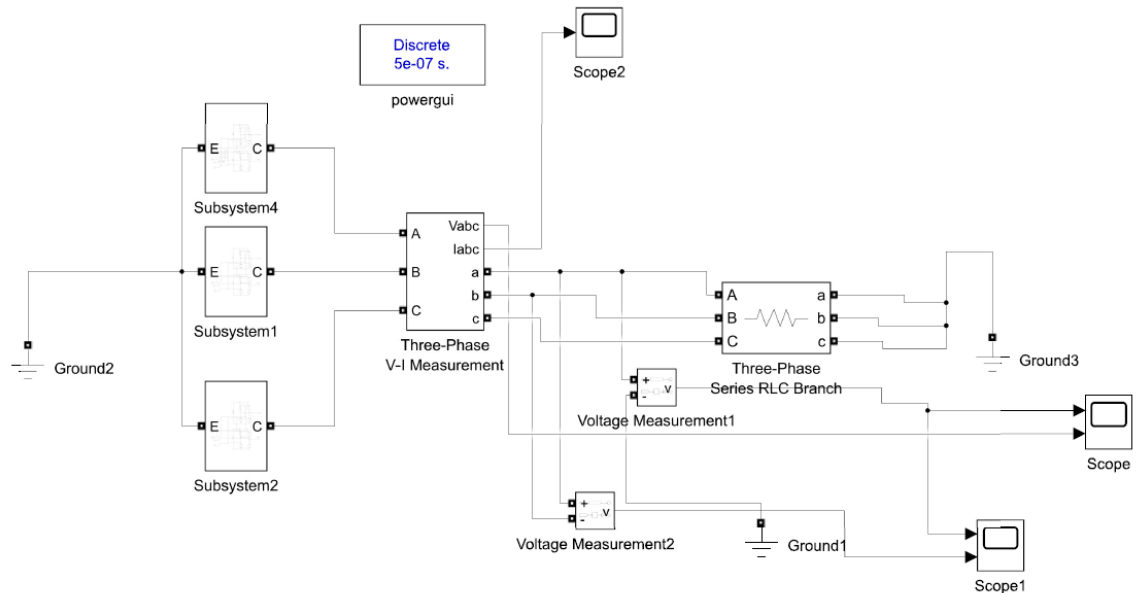


FIG 1: Block Diagram of 3 Phase 5 level Inverter

IV. EXPERIMENTAL RESULTS

The Grasshopper Optimization Algorithm was implemented in 5 level, 7 level cascaded H-bridge Inverters, upon which we obtained the Phase voltage and line voltage waveforms and the calculated THD for these waveforms. The first used MLI was the 5 level CHB multilevel inverter. In this inverter we had set the lower bound as 0 and the upper bound as 90 for most of the modulation indices, however for a couple of modulation indices the bounds were changed as the firing angles obtained, were deviating greatly from the ideal or were of close values. The figure given below is the MATLAB Simulink simulation model of the 3-phase 5 level cascaded H- bridge Multilevel inverter.

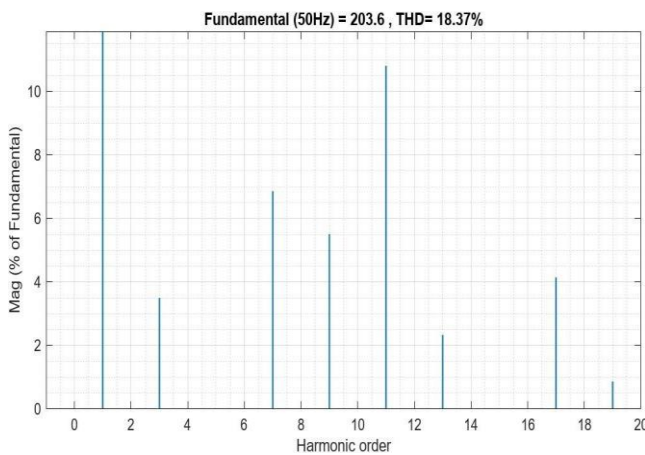


Fig 1. FFT analysis of Phase Voltage

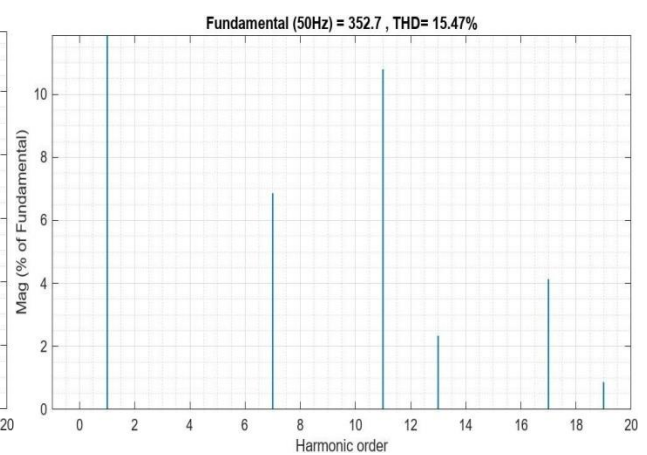


Fig 2. FFT analysis of Line Voltage

From the Simulink simulation model we have also obtained line-to-line voltage waveform of the 3-phase 5 level multilevel inverter. The waveform obtained is using the modulation index of 0.8 and the different line voltages of each phase is depicted in the figure. The FFT analysis was conducted on the model where we can clearly see the reduction of the 5th harmonic, along with the reduction of the 3rd and 9th harmonic as it is a 3-phase system. The THD of the line-to-

line voltage waveform is also less when compared to the THD of the Phase voltage waveform. The following graphs will show the wave forms of the 3 phases along with the R phase. The figure following that will show the THD obtained for the modulation index of 0.8 is for the line to line voltage waveform.

V. CONCLUSION

The use of cascaded H-Bridge Multilevel inverters has made designing and simulating them a much simpler task when compared to other types of multilevel inverters. The Grasshopper Optimization algorithm has proved to be highly effective when compared to other commonly used algorithms like Genetic algorithm and particle swarm algorithm. We can tell this as the objective function values obtained are much smaller (in 10^{-15} range) when compared to the range of other algorithms (in 10^{-6} range). The algorithm does take a slightly longer interval when compared to other optimizations, to calculate the switching angles and it entirely depends upon the number of iterations and search agents used, if the search agents are less, the time take to calculate the switching angles reduces. If the number of iterations were increased a better objective function value would certainly be obtained, however the time taken to execute will increase. In this project we have used 500 iterations and 50 search agents across all the simulations taking in and around 3-4 seconds to provide the expected results. When taking into account the comparison table that has been made we can observe that in all the MLI that were taken into consideration we have observed that for the Modulation indices in the range of 0.1 to 0.45 or 0.5, we have observed that the objective function values obtained are quite big (in the range of 10 to 0.001). This may be the cause of the lower modulation indices which doesn't provide with algorithm with much range to work with. On the other hand, for the ranges (0.5 to 0.8), the Objective function values are very small in comparison (in 10^{-15} range) hence providing much better and effective switching angles that will eliminate the selected harmonics. But in the case of modulation indices about 0.85 the objective function value again becomes higher. We can also argue that the same simulation run twice will not lead to the same answers. This is because of the random initialization that occurs in the code, the values upon repeated execution can lead to same or similar values causing slight changes in the THD calculated. To overcome this problem the bounding range was changed to the ideal range where that angles would lie. Upon executing using the changes the range the ideal or close to ideal switching angles were obtained, however this also posed another problem.

The problem was that the Objective function which was made to eliminate the selected harmonics (5th and 7th harmonics in this project) was not eliminating the selected harmonics. The harmonics even though present were resulting to lower THD when compared to the time when the bounding range was from 0 to 90. So a better or improved objective function would help in the reduction of this problem. Another keen observation can be that for the current MATLAB code can be used till 11 level after which it is unable to produce anymore angles. This could either be the limitation of the objective function or the limitation of the actual code itself. This can also be considered as another area of improvement. In summary, we can say that the grasshopper optimization algorithm is highly effective and accurate and compared to the other types of optimizations, it also provides a wide range of modulation indices that can be used, though it take a slightly longer time to execute when compared to the other optimizations.

REFERENCES

1. Selective Harmonic Elimination in a Multilevel Inverter Using Multi-Criteria Search Enhanced Firefly Algorithm MUHAMMAD KHIZER 1, SHEROZE LIAQUAT 2, (Graduate Student Member, IEEE), Muhammad Fahad Zia 3, (Member, Ieee), Saikrishna Kanukollu 4, Ahmed Al-Durra 4, (Senior Member, Ieee), And S. M. Muyeen 5, (Senior Member, Ieee) [2023].
2. Selective Harmonic Elimination in Five Level Inverter using Sine Cosine Algorithm Neha Sahu, Narendra D Londhe IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI-2017).
3. Selective Harmonic Elimination Based on Newton-Raphson Method for Cascaded H-bridge Multilevel Inverter International Journal of Power Electronics and Drive Systems International Journal of Power Electronics and Drive System (IJPEDS).
4. Barik, A. K., & Das, D. C. (2018). Expeditious frequency control of solar photovoltaic/biogas/biodiesel generator based isolated renewable microgrid using grasshopper optimisation algorithm. *IET Renewable Power Generation*, 12(14), 1659–1667.
5. Kundu, S.; Burman, A.D.; Giri, S.K.; Mukherjee, S.; Banerjee, S. Comparative study between different optimisation techniques for finding precise switching angle for SHE-PWM of three-phase seven-level cascaded H-bridge inverter. *IET Power Electron.* 2018, 11, 600–609.
6. W. T. Chew, W. V. Yong, S. L. Ong & J. H. Leong (2022) Harmonics Minimization in MLI Using Grasshopper Optimization Algorithm, *International Journal of Electronics*, 109:6, 1009-1034, DOI: 10.1080/00207217.2021.1966660.
7. S., G.; Chappa, A.; Rao, K.D.; Dawn, S.; Ustun, T.S. Development of an Enhanced Selective Harmonic Elimination for a Single-Phase Multilevel Inverter with Staircase Modulation. *Electronics* 2022, 11, 3902.



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