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Optimization of Selective Harmonic Elimination for Emerging Single-Phase Five-Level Inverter Using Genetic Algorithm

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***Abstract*—This study focuses on the analysis and experimental investigation of Selective Harmonic Elimination (*SHE*) for emerging single-phase multilevel inverter using Genetic Algorithm (*GA*), among the best algorithms for optimization. The employed inverter, a widely adopted emerging topology, uses fewer switches than conventional designs while delivering a five-level output voltage. *GA* solves transcendental nonlinear equations to find *SHE's* optimal commutation angles. Simulation outcomes closely align with theoretical predictions, demonstrating the method's simplicity compared to analytical techniques, suitability for inverter control, and cost-effectiveness for real-time implementation on a low-cost Arduino ATmega2560 Microcontroller. Theoretical analysis is validated through MATLAB/Simulink simulations and a hardware prototype built with efficient electronic components. Both simulation and experimental findings validate the resilience and efficacy of the presented modulation technique for emerging single-phase five-level inverters.**

Keywords— Digital signal processing, Genetic algorithms, Multilevel converters, Optimization methods, Pulse width modulation inverters.

I. Introduction

Multilevel inverters have emerged as a prominent area of research in power electronics owing to their capacity to generate high-voltage outputs with enhanced power quality. These converters are extensively utilized in multilevel resonant inverters; distributed generation systems (*DGS*); and grid-connected applications [1]-[3].

The literature identifies two main categories of multilevel inverters: conventional and emerging. Conventional topologies as the Neutral Point Clamped (*NPC*); the Cascaded H-Bridge (*CHB*); and the Flying Capacitor (*FC*) inverters. Recent innovations include multilevel inverters with a single source, inverters with fewer devices, inverters with soft switches, and inverters with an uneven number of levels [4]-[7]. Emerging topologies are gaining attention for their cost-effectiveness, reduced switching losses, low total standing voltage (*TSV*), and simpler control requirements compared to conventional designs.

Modulation, the process of generating gating signals for converter semiconductor devices, is categorized by switching frequency: fundamental-switching frequency modulation and high-switching frequency modulation. Widely used high-frequency techniques as Sinusoidal PWM (*SPWM*) and Space Vector PWM (*SVPWM*) [8]-[9], whereas fundamental-frequency methods include Selective Harmonic Elimination (*SHE*); optimal switching angle modulation; and nearest-level (*NL*) modulation [10]. Advances in digital control platforms, such as high-performance processors, DSPs, FPGAs, and embedded controllers have made fundamental-frequency modulation increasingly practical [11]. Implementing *SHE* requires solving nonlinear transcendental equations to determine optimal switching angles. Solutions are obtained using (a) algebraic approaches; (b) numerical techniques; or (c) heuristic and evolutionary algorithms (*EAs*) [12]. When faced with difficult optimization issues, heuristic algorithms excel in finding approximate optimal solutions. In this regard, we can cite a number of algorithms, such as Particle swarm optimization (*PSO*); Flower Pollination Algorithm (*FPA*); Gravitational Search Algorithm (*GSA*); Grey Wolf Optimizer (*GWO*); Artificial Neural Networks (*ANN*); Artificial Bee Colony (*ABC*); Ant Colony Optimization (*ACO*); Salp Swarm Algorithm (*SSA*); Generalized Pattern Search (*GPS*) [13]-[16].

Genetic Algorithm (*GA*) were first introduced by John Holland and his colleagues in 1975 as a model inspired by biological evolution, making them one of the earliest evolutionary algorithms. When properly configured within a data space, *GA* provides an effective approach for solving optimization problems [17]. Finding the optimal solution to a problem while taking into account a number of criteria pertaining to system properties and restrictions is what optimization is all about. By using random processes to produce fresh generations of solutions, the best one is culled from a population of potential solutions. Applying selection, crossover, and mutation in sequential order to the present population and repeating until a halting condition is reached are the three operators that this method relies on [18]-[19].

This research investigates the use of Genetic Algorithm for implementing *SHE* in emerging single-phase five-level inverter. The method addresses nonlinear transcendental equations to identify optimal switching angles and mitigate low-order harmonics. *GA* is selected due to its straightforward structure, ease of implementation, limited parameter requirements, and ability to deliver accurate solutions with good convergence. The key benefits of the proposed study are its simplicity and the low-cost experimental implementation of the system. By delving into the principles, applications, and benefits of Arduino-based controlled inverter, this research seeks to be a reference for students and engineers interested in developing converters applications using this kind of open-source technology.

This paper is set up like this: Section II talks about the materials and methods, including the operational principles of the five-level inverter and the *GA*-based *SHE* implementation. Section III resumes the simulation and experimental findings, while Section IV provides concluding remarks.

II. Materiels and Method

A. The Multilevel Inverter Operation

Fig. 1 illustrates the structure of the 5-level inverter. The 5-level inverter is comprised of 6 power switches and 2 independent *DC* sources, which work together to generate a five-level output voltage. This configuration requires fewer switches than the conventional 5-level *CHB* inverter [20].

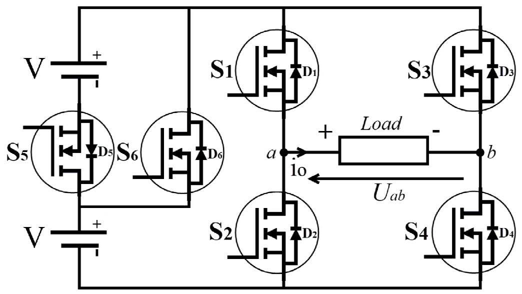

Fig. 1. Topology of the 5-level inverter.

The 5-level inverter structure, which allows for the generation of five separate output voltage levels (+V; +2V; 0; -V; and -2V) is shown in Table I.

TABLE I. Switching States of the Five-level Inverter

Interval	ON switches	OFF switches	U_{ab}
$[0, \theta_1]$	S_2, S_4	S_1, S_3, S_5, S_6	0
$[\theta_1, \theta_2]$	S_1, S_4, S_6	S_2, S_3, S_5	$+V$
$[\theta_2, \pi/2]$	S_1, S_4, S_5	S_2, S_3, S_6	$+2V$
$[\pi/2, \theta_3]$	S_1, S_4, S_5	S_2, S_3, S_6	$+2V$
$[\theta_3, \theta_4]$	S_1, S_4, S_6	S_2, S_3, S_5	$+V$
$[\theta_4, \theta_5]$	S_2, S_4	S_1, S_3, S_5, S_6	0
$[\theta_5, \theta_6]$	S_2, S_3, S_6	S_1, S_4, S_5	$-V$
$[\theta_6, 3\pi/2]$	S_2, S_3, S_5	S_1, S_4, S_6	$-2V$
$[3\pi/2, \theta_7]$	S_2, S_3, S_5	S_1, S_4, S_6	$-2V$
$[\theta_7, \theta_8]$	S_2, S_3, S_6	S_1, S_4, S_5	$-V$
$[\theta_8, 2\pi]$	S_1, S_3	S_2, S_4, S_5, S_6	0

B. The Selective Harmonic Elimination Using Genetic Algorithm

Fig. 2 shows the anticipated output voltage waveform of the inverter. The waveform includes two positive voltage levels, indicating that one harmonic can be eliminated. Based on Fourier analysis, the inverter output voltage $U_{ab}(t)$ is represented by the trigonometric expression in equation (1):

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

Where: a_0=0 and a_n=0 since $U_{ab}(t)$ is a periodic odd function, while b_n is determined using the expression given in equation (2):

$$b_n = \frac{2}{T}\int_0^T U_{ab}(t)\sin(n\omega_s t)dt \quad (2)$$

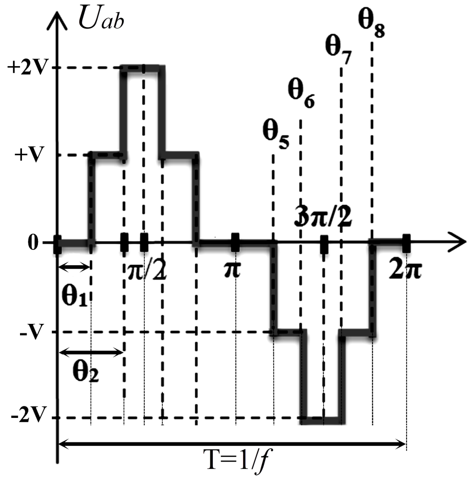

Fig. 2. Waveform of the five-level output voltage.

By integrating $U_{ab}(t)$ over $[0, 2\pi]$ and performing standard algebraic simplifications, equation (2) is reformulated as equation (3).

$$b_n = \frac{4V}{n\pi}\left(\cos(n\theta_1) + \cos(n\theta_2)\right) \quad (3)$$

Substituting equation (3) into (1) yields the expression for the inverter output voltage $U_{ab}(t)$ as given in (4).

$$U_{ab}(t) = \sum_{n=1}^{\infty}\left(\frac{4V}{n\pi}\left(\cos(n\theta_1) + \cos(n\theta_2)\right)\right)\sin(n\omega_s t) \quad (4)$$

For n=1, the inverter output voltage $U_{ab}(t)$ can be represented by the fundamental harmonic h_1, as shown in equation (5).

$$h_1 = \frac{4V}{\pi}\left(\cos(\theta_1) + \cos(\theta_2)\right) \quad (5)$$

The third harmonic h_3 is defined by equation (6).

$$h_3 = \frac{4V}{3\pi}\left(\cos(3\theta_1) + \cos(3\theta_2)\right) \quad (6)$$

By solving the following system of nonlinear equations (7), the ideal commutation angles for a 5-level inverter can be derived, according to studies in [21] and [22] on the use of *SHE*:

$$\begin{cases} 0 = \cos(3\theta_1) + \cos(3\theta_2) \\ MI = \dfrac{1}{k}\left(\cos(\theta_1) + \cos(\theta_2)\right) \end{cases} \quad (7)$$

In which k is number of angles, and MI is given by (8).

$$MI = \frac{\pi h_1}{4kV} \quad (8)$$

It's also important that the best communication angles for a five-level converter meet the conditions in equation (9).

$$0 < \theta_1 < \theta_2 < \frac{\pi}{2} \tag{9}$$

It is vital to have an objective function in optimization that seeks to remove undesirable harmonics while keeping the fundamental component at its set magnitude. Thus, equation (10) defines the objective function.

$$F(\theta_1, \theta_2) = \left(\sum_{n=1}^{2} \cos(\theta_n) - k \times MI \right)^2 + \left(\sum_{n=1}^{2} \cos(3\theta_n) \right)^2 \tag{10}$$

By minimizing equation (10) while keeping the constraint in equation (9), we can determine the ideal commutation angles. We use the genetic approach to solve equation (7) because it is nonlinear. Fig. 3 shows the *GA* flow diagram, which breaks down the method into five distinct steps: (1) Population initialization; (2) Objective function evaluation; (3) Selection; (4) Crossover; and (5) Mutation.

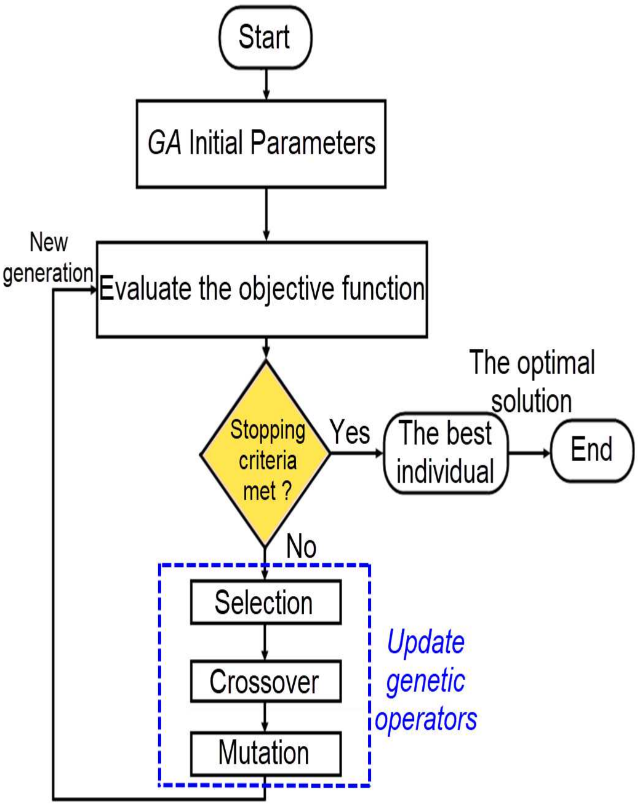

Fig. 3. The GA flowchart.

The genetic algorithm's parameters are displayed in Table II. The academic community widely recognizes that determining the parameters of metaheuristic algorithms is not a precise science. Actually, optimizing these settings is a problem in and of itself. As a result, the *GA* parameters including population size, iteration count, acceleration coefficient, and inertia weight do not have a standard protocol for their configuration. A literature review can reveal the optimal parameter ranges. Furthermore, users have the option to tweak the parameters and assess the results, just like in this study.

TABLE II. SELLECTED PARAMETERS OF THE GA.

Parameter	Objective function value
Size of the population	50
Number of Generations	100
Quantity of variables	3 (MI, θ_1, θ_2)
Interval limit	$\theta_1 \in [0, 90]$
	$\theta_2 \in [0, 90]$
	$MI \in [0.1, 0.85]$
number's length in binary	10
Selection	*Roulette*
Crossover	*Random*
Probability of Crossover	100 %
Mutation	*Random*
Probability of Mutation	5 %

C. Digital PWM signals generations with Arduino ATmega2560 Microcontroller

Arduino mega board is shown in Fig. 4. It is a printed circuit that features an ATmega2560 microcontroller operating at 16 MHz, along with various other electronic components. It is commonly used in electronics projects to receive, analyze, and generate electrical signals [23].

We chose Arduino technology due to its advantages: it provides an open-source platform and allows programs to be uploaded directly to the device without needing a hardware programmer. Additionally, modifying or updating the program does not require changes to the hardware. The Arduino mega has 54 pins (14 digital inputs/outputs pins and 6 analog inputs pins); 8 KB of RAM; 4 KB of EEPROM; and 256 KB of flash memory [24].

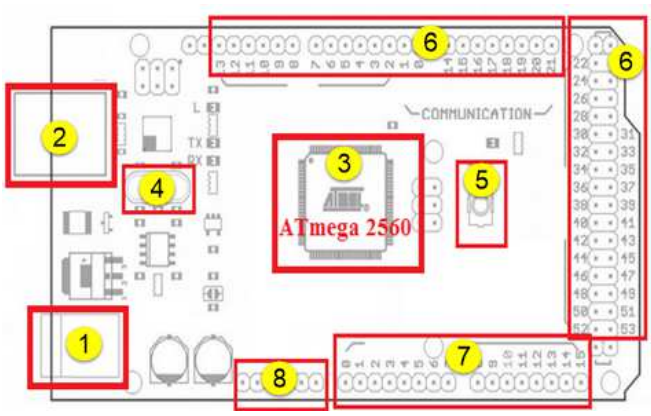

Fig. 4. The Arduino mega board, (1) Power supply, (2) USB Connector, (3) Microcontroller ATmega2560, (4) Quartz 16 MHz, (5) Reset button, (6) Digital I/O pins, (7) Analog input pins, (8) Other pins.

In inverter-based systems, output voltage regulation is commonly achieved using pulse-width modulation (*PWM*), which remains the most efficient control technique. Modern platforms such as *PIC* microcontrollers, *DSP* boards, *ARM* Cortex-M processors, Arduino modules, and dSPACE systems integrate dedicated peripherals for *PWM* generation.

In this study, the *TIMER* module of the Arduino ATmega2560 is configured to operate as a digital *PWM* generator, producing signals with programmable duty cycle and frequency. The timer functions as a counter register that increments or decrements in synchronization with the system clock, thereby enabling precise time measurement and signal generation [25].

III. RESULTS DISCUSSION

Using the MATLAB/Simulink environment, simulations were conducted to test the 5-level inverter topology and evaluate the Genetic Algorithm's performance. We used the Fast Fourier Transform (*FFT*) tool for harmonic analysis and the MATLAB Editor to implement the *GA*. Within the valid interval [0.1, 0.85], the switching angles corresponding to each modulation index (*MI*) were computed. Fig. 5 shows how the switching angles θ_1 and θ_2 change in relation to *MI*.

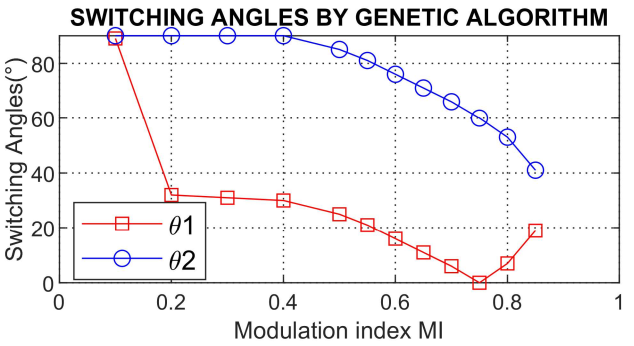

Fig. 5. The angles θ_1 and θ_2 versus *MI using Genetic Algorithm.*

A laboratory-scale prototype of the single-phase 5-level inverter was developed employing six MOSFET switching devices, two independent *DC* sources, and an Arduino ATmega2560 board. The setup also integrated an oscilloscope and a personal computer running MATLAB/Simulink for monitoring and analysis. The constructed hardware arrangement is illustrated in Fig. 6.

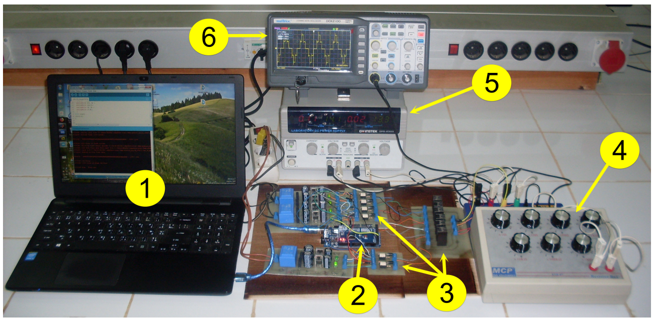

Fig. 6. Hardware implementation of the single-phase five-level inverter: (1) PC running MATLAB/Simulink; (2) Arduino ATmega2560 board; (3) Inverter with gates drivers; (4) Resistive load; (5) Dual DC sources; (6) Digital oscilloscope.

To conduct both simulation and experimental validation of the genetic algorithm, two tests were performed using different modulation index values for comparison. The matching switching angles used for testing the 5-level inverter are displayed in Table III. We maintained a constant *DC*-link voltage of 10 V and a fundamental frequency of 50 Hz.

TABLE III. CHOSEN SWITCHING ANGLES TO EVALUATE THE 5-LEVEL INVERTER

Test	Parameters	Objective function value
Case-1	θ_1=30°, θ_2=60°	Without Genetic Algorithm
Case-2	*MI*=*0.85*, θ_1=19°, θ_2=41°	5.3e-08

Fig. 7 displays the 5-level inverter's simulated phase voltage for Case 1, while Fig. 8 displays the associated harmonic spectrum. As expected, all harmonic orders are present with a total harmonic distortion voltage (*THDv*) of 30.73 percent.

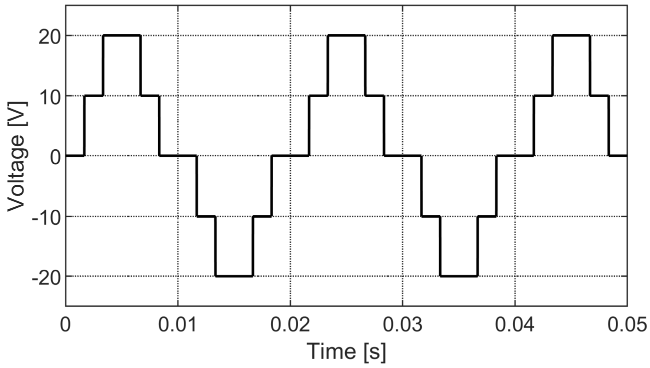

Fig. 7. Phase voltage waveform of the 5-level inverter for Case 1 obtained through simulation.

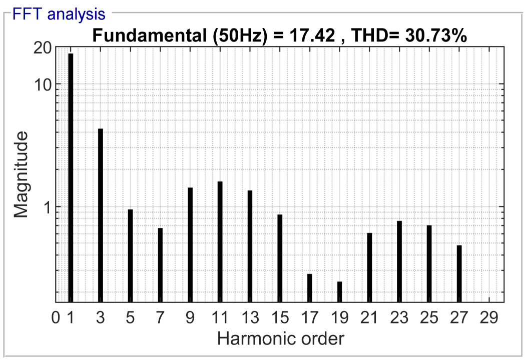

Fig. 8. FFT spectrum of the inverter output voltage obtained through simulation for Case 1.

Fig. 9 displays the 5-level inverter's simulated phase voltage for Case 2, while Fig. 10 displays the associated harmonic spectrum. The 3rd harmonic and its multiples are effectively eliminated, resulting in a notably reduced *THDv* of 17.41%.

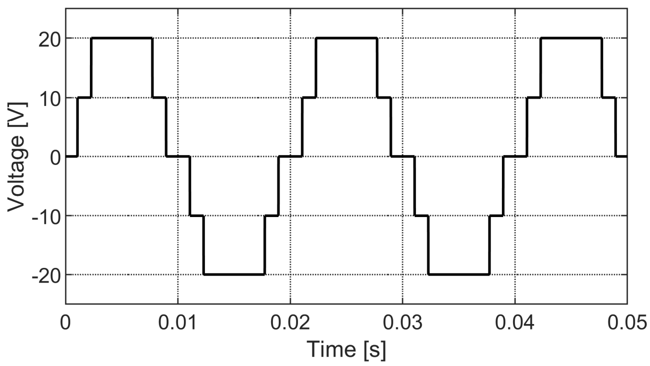

Fig. 9. Phase voltage waveform of the 5-level inverter for Case 2 obtained through simulation.

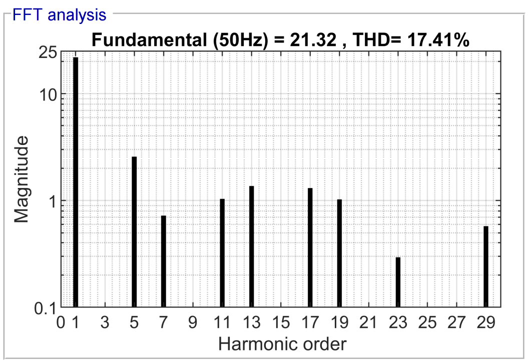

Fig. 10. FFT spectrum of the inverter output voltage obtained through simulation for Case 2.

Fig. 11 presents the experimental voltage of the 5-level inverter for Case 1, and the associated harmonic spectrum is depicted in Fig. 13(a). The *FFT* analysis clearly indicates the presence of all harmonic orders, with a measured *THDv* of 30%.

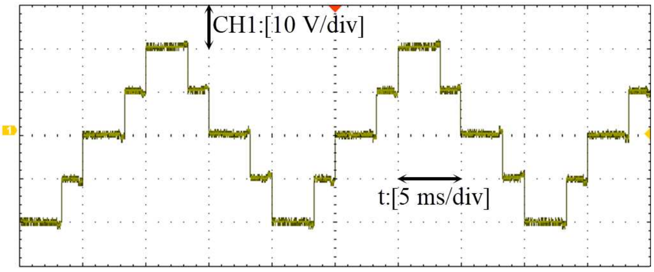

Fig. 11. The experimental phase voltage waveform of the 5-level inverter for Case 1.

Fig. 12 shows the experimentally obtained voltage of the 5-level inverter for Case 2, and the associated harmonic spectrum is depicted in Fig. 13(b). The elimination of the third harmonic and its multiples is confirmed by the *FFT* analysis, which shows a reduction of the measured *THDv* to 17.5%.

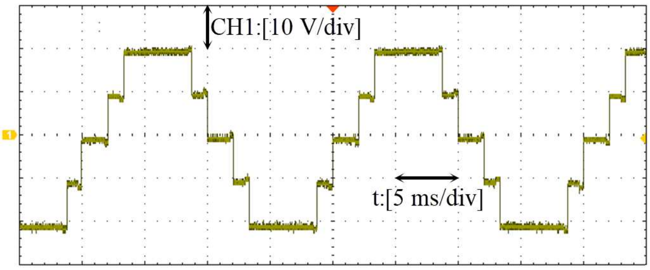

Fig. 12. The experimental phase voltage waveform of the 5-level inverter for Case 2.

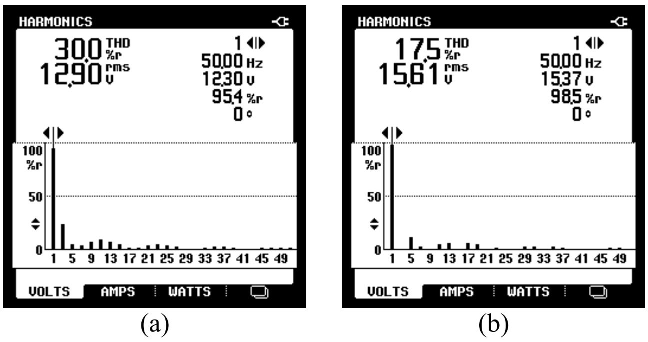

Fig. 13. Experimental harmonic spectrum of the 5-level inverter output voltage. (a): Case 1. (b): Case 2.

The 5-level inverter's simulated phase voltage for Cases 1 and 2 is displayed in Figures 7 and 9, and the corresponding experimental results are shown in Figures 11 and 12. The simulation and experiment show a good match, which is further supported by the *FFT* analysis that is compiled in Table IV. The outcomes, which came from a simple implementation, are in line with earlier research findings [14], [21], and [22].

TABLE IV. COMPARISON BETWEEN THE ACHIEVED THD_V

Test	*THDv* (%) of Simulation	*THDv* (%) of Experimental
Case-1	30.73	30.0
Case-2	17.41	17.5

IV. CONCLUSION

This work aimed to examine the implementation of selective harmonic elimination for a single-phase 5-level inverter utilizing an evolutionary algorithm. Simulations carried out in MATLAB/Simulink confirmed the effectiveness of the proposed approach, while experimental validation was performed on a cost-effective Arduino board. The results demonstrated that *SHE* modulation is a practical and efficient technique for multilevel inverters, successfully eliminating the targeted harmonics and reducing the *THDv* to 17.5%.

The findings emphasize the possible advantages of intelligent algorithms in power electronic systems. Future work could focus on extending this approach to other emerging multilevel inverter topologies and exploring alternative optimization algorithms. Additionally, applications such as renewable-energy-fed inverters, grid-connected systems, and multilevel inverters for industrial motor drives present promising research directions. Ultimately, integrating such solutions into sustainable energy systems can contribute to meeting the growing electricity demand, alleviating the effects of natural disasters and global issues, while diminishing air pollution and curtailing climate change.

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People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

Djelfa on November 11, 2025

FST 21 /FST/2025

Djelfa University
LAADI
Laboratoire d'Automatique Appliquée et Diagnostics Industriel

Applied Automation and Industrial Diagnostic Laboratory

Acceptance Letter

INVITATION

Affiliation
LIST Laboratory, Department of Electrical Systems Engineering, Faculty of Technology, University of M'hamed Bougara of Boumerdes, Boumerdes, Algeria

Dear Alla Eddine TOUBAL MAAMAR,

On behalf of the Program Committee, we are delighted to inform you that your work :

Paper ID : 35 / Track : 1

Title: Optimization of Selective Harmonic Elimination for Emerging Single-Phase Five-Level Inverter Using Genetic Algorithm

Co- Authors : Aimad BOUDOUDA, Mourad NAIDJI, Radu PORUMB, Touhami ABDELOUAHED, Saad MEKHILEF

has been accepted for presentation at the IEEE 2025: 6th International Conference on Power Electronics and Their Applications, ICPEA 2025 .

To secure your presentation slot, please make sure that at least one of the authors attends the conference and presents the paper, and register for the conference following the requirements announced on the conference website and sent to you via email. We strongly advise you to make the necessary arrangements as soon as possible.

The organizing committee of IEEE ICPEA 2025 is committed to supporting your participation in this important meeting of the international scientific community. If you require any additional information, please do not hesitate to contact us.

We look forward to welcoming you to Djelfa for the IEEE ICPEA 2025 event.

Best regards,

General Chair

The 6th International Conference on Power Electronics and their Applications
ICPEA 2025
18-20 November 2025
Ghardaia Algeria

General Chair
Prof. Abdellah Kouzou

Applied Automation and Industrial Diagnostic Laboratory
Faculty of Science and Technology
University of Djelfa, Algeria

Email : laadi@univ-djelfa.dz

Program

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Ghardaïa, Algeria | 18-20 November 2025

8 h – 9 h 00	**Registration**
9 h 00 – 09 h 45	**Opening Ceremony (Conference room)** **Prof. Ilyes Bensaci** (Rector of Ghardaïa University) **, Prof. El Hadj Ailam** (Rector of Djelfa University)
09 h 45 – 10 h 45	**Plenary Session 1** **Fast Electric Vehicles Charging Stations Infrastructure, Control, and Grid Interaction** **Professor Haitham A Abu-Rub** College of Science and Engineering, Hamad Bin Khalifa University, Qatar **Chair : Prof. Said Drid**
11 h 15 – 11 h 30	**Coffee break**
11 h 30 – 12 h 30	**Plenary Session 2** **Rethinking Grid Resilience: The Iberian Wake-Up Call** **Professor Dr. Sertac Bayhan** College of Science and Engineering, Hamad Bin Khalifa University, Qatar **Chair : Prof. Abdellah Kouzou**

Program

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18/ 11 / 2025 / Afternoon : Oral Sessions (A)

	Session 1	Session 2	Session 3
Chairs	**Dr Abdelhalim Rabehi, Dr Fayçal Chouia**	**Pror. Abdallah Zegaoui, Dr Aissa Rebai**	**Pror. A. Kaabech, Dr Mohamed Elbar**
13h00- 13h15	**ID 19.** Leila Lalia MIZAT et al., Adaptive Under-Voltage Load Shedding for Distribution Systems with High DG Penetration	**ID 23.** Rabie Benaissa et al., Advanced Control Using an Interval Type 2 Fuzzy Neural Network for The Double Stator Interior Permanent Magnet Synchronous Motor Fed by a Nine Switch Inverter	**ID 96.** Ahmed Lakhder Kouzou et al., Seamless Transition Between Grid-Following and Grid-Forming Modes for Grid-Tied Virtual Synchronous Generator with LCL Filter
13h15 - 13h30	**ID 21.** Fatima Zohra OULAD LAID et al., Hybrid LSTM Forecasting Models with Dual Signal Decomposition: A Comparative Study for Energy Consumption	**ID 40.** Rafik Dembri et al., Adaptive Interval Type-2 Fuzzy-PI Control for Improved Dynamic Power Regulation in DFIG-Based Wind Energy Systems	
13h30 - 13h45	**ID 84.** Soundous Sekayar et al., Hybrid ANN-Based Day-Ahead PV Power Forecasting with Multi-Decomposition: Tindouf Case Study	**ID 46.** Farid Hadjrioua et al., A Simulation Framework for Assessing Power Losses in Photovoltaic Modules Induced by Cell Cracking	

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18/ 11 / 2025 : Poster Sessions

	Session 1	Session 2	Session 3
Chairs	Dr Abdelouahab Khattara, Dr Naas Charrak	Dr A. kina, Prof. Abdelrezak Gacemi	Dr M. Sellah, Dr Muhhamed Abu-Rub
15h 35-16 h00	**ID 7.** Fadila Barkat et al., Assessing the Technical Viability of a Stand-Alone Solar-Powered EVs Charging Station in a Very Hot Location: The Case Study of Ghardaïa, Algeria	**ID 47.** Antar Beddaret al., Hardware-in-the-Loop Based Energy Management Enhancement in Grid-Connected PV Systems Employing TI TMS320F28379D	**ID 43.** Yehya Houam et al., Multi-Objective Optimal Design of an Off-Grid Hybrid Renewable Energy System Ensuring Reliability and Minimizing Life Cycle Costs
	ID 20. Abdelkader Firah et al., Design and Control of Photovoltaic/Battery Microgrid Based on Wild Horse Optimizer	**ID 69.** Assam Benbaha et al., Experimental Comparison of Sunflower Oil and Brick Pieces as Heat Storage Materials for Solar Cooking Applications	**ID 32.** Idris Azizi et al., Field Oriented Control of Permanent Magnet Synchronous Motor with Synergetic Control
	ID 97. Noureddine Benbaha et al., Evaluation of a PV-Battery-Grid System: Case Study in the Ghardaia Region		

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18/ 11 / 2025: Virtual Sessions

	Session 1	Session 2	Session 3
Chairs	**Dr Ali Teta, Pror. Amar Benaissa**	**Pror. A. Bellaouar, Dr Belgacem Bekkar**	**Prof. Salam Abudura, Dr Sidali Aissat**
13h00 - 14h15	**ID 1.** Janani C., et al., Advancing PV Array Reconfiguration with Hybrid Multi-Objective Improved Wild Horse Optimization	**ID 64.** SELLAH Mourad et al., High-Performance Photovoltaic-Fed DOEWIM Drive: A Backstepping and Reduced-Order Observer Approach with Matrix Converter Integration	**ID 62.** Hicham Sayhi et al., Experimental Implementation of FS-Predictive Current Control with MPPT-OTC for Performance Optimization of PMSG-Based Wind Energy Systems
13h15 - 13h30	**ID 10.** Hala Lalaymia et al., Performance Evaluation of GEO and GWO for Optimal Photovoltaic DG Placement in a 33-Bus Distribution Network	**ID 48.** Djamel Derkouche et al., Synergetic Control of Multiphase Induction Wind Generator Associated with Flywheel Energy Storage System Controlled by Smooth Sliding Mode	**ID 79.** Marcellin Jay C. Panes, Renyl B. Barroca, Experimental Performance Analysis of Air- and Water-Cooled Thermoelectric Generator Systems under Low-Temperature Renewable Heat Conditions
13h30 - 13h45	**ID 74.** Khaoula Nermine Khallouf et al., A Comparative Study Between Fractional Order PI and Classic PI Control for Power Quality Improvement in Microgrid Connected System	**ID 2.** Said Benkaihoul et al., Golden Jackal Optimizer-Based PI Controller for Efficient MPPT in Photovoltaic Systems	**ID 60.** Ismail Benmiloud et al., Dual Star Induction Motor EV Drive Using Nine Switch Quasi-Z-Source Inverter

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	Session 4	Session 5	Session 6
Chairs	**Dr B. Kourich, Prof. Benalia Mhamedi**	**Dr C.A. Mosbah, Dr Dahmane Djandaoui**	**Dr Fares Fenniche, Dr Fatma Bouchelga**
14h30 - 14h45	**ID 18.** Mohammed BENMILOUD et al., Design and Evaluation of a Double-Loop ADRC Scheme for DC–DC Push–Pull Converters	**ID 93.** Abdelghani Guechi et al., Performance Analysis of Long-Distance HVDC Transmission for Solar Power Transport in Algeria: Case Study of Ghardaïa – Tamanrasset Line	**ID 35.** Alla Eddine TOUBAL MAAMAR et al., Optimization of Selective Harmonic Elimination for Emerging Single-Phase Five-Level Inverter Using Genetic Algorithm
14h45 - 15h00	**ID 29.** Abdesselam Belkheir et al., Study and Control of Totem-Pole PFC Converter Based on a PI–MPC Control Strategy	**ID 37.** Kayyam Saikumar et al., A 300 kW GaN-Based Vector-Controlled Synchronous Motor Drive for EV Traction	**ID 25.** Mathew John Kamara et al., Design of a Buck–Boost Converter with Parasitic Elements Using a Sliding Mode Controller
15h00 - 15h15	**ID 52.** Camelia Ait Hammouda et al., Advanced MSOGI Virtual Impedance Control for Power-Sharing Improvement in Standalone Microgrids	**ID 45.** Abdelkader ELMEDDAH Djalloul ACHOUR, PSO and ACO-Optimized Cascade PI Control of DC-DC Buck-Boost Converters for High-Performance DC Machine Speed Regulation in Mecha-Electrical Wind Pumping Systems	**ID 26.** Ali Teta et al., A robust framework for secure partial shading detection in photovoltaic systems under adversarial attacks
15h15 - 15h30	**ID 66.** Nassim Zemirline et al., Experimental Realization of the Second and Third Stages of a Solid-State Transformer	**ID 99.** Kacha Kalinka et al., Optoelectronic Tuning of Sputtered ZnO–Au–Ag (NPs) Films through Gold Interlayer Design	**ID 56.** Zine Eddine Touhami Ternifi et al., Experimental Evaluation of Temperature Estimation Methods for a Photovoltaic Module
15h30 – 15h45	**ID 57.** Billel Boumaaraf et al., Enhancing Electrical Efficiency of a Solar Module Using a Cooling System: Experimental Case Study	**ID 75.** Soufian Khettab et al., Software-in-the-Loop Validation of a PEC9-Based Multifunction Solar Active Filter	**ID 80.** Marcellin Jay C. Panes, Village-Scale Off-Grid Solar Microgrids: Advancing Rural Electrification through Distributed Generation and Storage
15h45 – 16h00	**ID 72.** Youcef Belkhier et al., Resilient Power Management for Unmanned Small-Scale Hybrid Diesel–Electric Shipboard Microgrids	**ID 86.** Guerbazi Mohamed El Amine et al., CFD-Driven Optimization of Channel Cross-Section Geometry in Planar and Tubular PEMFCs: Enhancing Power Density and Reducing Pressure Drop	**ID 90.** Sarah K. Sedjar, Physically Grounded Electro-Thermal and Structural Modeling of a High-Efficiency Monocrystalline PV Cell for Embedded Energy Systems
16h00- 16h15	**ID 24.** Belkaid Rahma, Boukhalfa Ghoulam Allah, Robust Direct Torque Control of Dual Star Induction Motor with MOA-Based Third Order Sliding Mode Control	**ID 77.** Amel Kasri et al., Real-Time SIL Validation of Dual-Stage Robust Predictive Control for Multiphase Wind Generators	

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8 h 30 – 9 h 30	**Plenary Session 3** **Power electronics and hybrid transformers in distributed energy system - opportunities and challenges** **Professor Mariusz Malinowski** Warsaw Technical University, Warsaw, Poland **Chairs : Prof. Lakhder Moukrani and Professor Mostefa Mohamed-Seghir**
09 h 30 – 10 h 30	**Presentation of IEEE Algeria Section** **Professor Abdellah Kouzou** University of Djelfa, Algeria **Chairs : Prof Soumia KOUADRI MOUSTEFAI**
10 h 30 – 11 h 00	**Coffee break**

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	Session 1	Session 2	Session 3
Chairs	**Dr Ali Teta, Pror. Amar Benaissa**	**Pror. A. Bellaouar, Dr Belgacem Bekkar**	**Prof. Salam Abudura, Dr Sidali Aissat**
13h00 - 14h15	**ID 49.** Mohamed ELBAR et al., Deep Learning-Based Dynamic Harmonic Compensation in Three-Phase Systems Using DNN-Controlled Shunt Active Power Filter	**ID 6.** Laribi Slimane et al., Parameter Identification of a Photovoltaic Module Operating in Desert Conditions: Application to the Adrar Region	**ID 51.** Ahmed Mokhtari, Mohamed Amara, Enhancing the Stability of STATCOM Topology under Three-Phase Short Circuit Fault Using Fuzzy Logic Controller
13h15 - 13h30	**ID 36.** Ali Abderrazak Tadjeddine et al., Intelligent Power Flow Management for a Photovoltaic El Abiodh Sidi Cheikh Grid: A PSO-Based Approach	**ID 82.** Aissa Kheldoun, Hamza Belmadani, Experimental Evaluation of Predictive Torque Control for B6 and B4 Inverter-Fed Induction Motors	**ID 16.** Assala Guergouri et al., Performance Evaluation and Comparative Analysis of NPC, H-Bridge, and Flying Capacitor of Five-Level Converters
13h30 - 13h45	**ID 50.** Yousra Lzgheche et al., Evaluation and Comparison of MPPT Methods in Shaded PV Systems Using HHO and GA	ID 89. Mouhcen El-hadi Dahmoun et al., Integrating Virtual Reality in Electrical Machine Learning: An Experiential Approach to Motor Component Understanding	**ID 87.** Younsi Z. et al., Theoretical Insights and Numerical Simulation of $CdS/CuInS_2$ Heterojunction Solar Cells for Enhanced Performance Analysis

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12 h 30 – 13 h 00	**Closing Ceremony**
13 h 00	**Lunch**