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Research Article

BACTERIA FORAGING OPTIMIZATION ALGORITHM (BFOA) FOR THD SUPPRESSION IN DC-AC CONVERTER

[1,] * N.M.SpencerPrathap Singh and [2]T.Ajitha

[1]Professor, Department of EEE, C.S.I. Institute of Technology, Thovalai, Kanyakumari, Tamilnadu, India.
[2]Assistant Professor, Department of ECE, St.Xavier's Catholic College of Engineering, Chunkankadai, Kanyakumari, Tamilnadu, India.

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ABSTRACT

The main goal of this paper is to use the Bacteria Foraging Optimization Algorithm (BFOA) to reduce the harmonics in the voltage source inverter that is connected to the non-linear load. Using the Bacteria foraging Optimization Algorithm (BFOA), the optimal values of the PI controller constants are calculated. Both software and hardware uses the tuned values of the PI constants.PIC microcontroller is employed for hardware verification while MATLAB tool is utilized for software. Software analysis and experimental proof demonstrate that the total harmonic distortion is lower than the IEEE standard.

Keywords: voltage source inverter, Bacteria Foraging Optimization Algorithm, Total harmonic distortion, PI controller, PIC microcontroller.

INTRODUCTION

Single-phase full-bridge inverters are DC-AC converters used in renewable energy applications, electric vehicles, adjustable speed drives, FACTS devices, and UPS. Commonly used in the event of power outages to supply power to critical loads that require pure sinusoidal voltage at the specified magnitude, frequency, and low total harmonic distortion (THD), DC-AC inverters typically operate in pulse width modulation (PWM) mode and switch between different circuit topologies.[1]-[3]. The deviation of the waveform from the sinusoidal shape must be detected and analyzed before attempting to devise control techniques to minimize the distortion. Numerous enlightening publications on the measurement of harmonics under steady-state and non-stationary settings employing PWM method, Switching angles, Hopfield Neural networks, LC filter, and interphase transformers in diverse applications are available in the technical literature. [4]-[14]

PWM techniques that are commonplace include sinusoidal and modified sinusoidal PWM, as well as phase displacement approaches. There are intriguing techniques for removing harmonics in full bridge inverters, including Unipolar and Bipolar notches, Waveform stepping, and other options. The single phase full bridge inverter has issues such harmonic torques, interferences, oscillations, heating, etc. because of the presence of harmonics. [15]-[17]. The single phase full bridge inverter has issues such harmonic torques, interferences, oscillations, heating, etc. because of the presence of harmonics. The harmonic reduction method for the inverter's non-linear load is put out in this study. The voltage distortion in a stand-alone inverter is mostly brought on by the drop across the LC filter's inductor. Bacteria Foraging Optimization algorithm (BFOA) THD values are proposed and evaluated in comparison to both hardware and software outcomes. The Bacteria Foraging Optimization Algorithm effectively reduces the harmonics in the inverter.

***Corresponding Author: N.M.SpencerPrathap Singh,**
1Professor, Department of EEE, C.S.I. Institute of Technology, Thovalai, Kanyakumari, Tamilnadu, India.

INVESTIGATION OF A SINGLE PHASE VOLTAGE SOURCE INVERTER

The bipolar voltage switching with sinusoidal pulse width modulation-based voltage-controlled single-phase full-bridge inverter's operating principles and mathematical model are examined in this part. Ideal is to assume all elements. The control variable u has two distinct topologies for the power switches, 0 and 1. Switches S_A and S_D must be turned on for u = 1. u = 0 if switches S_B and S_C are turned on. [2].

First Topology :Based on SPWM, the system can produce a positive half sine wave for the load while S_A and S_D are on (u = 1). The equivalent circuit is shown in Fig. 1. The state-space equation is expressed using the circuit topology as follows:

$$\left\{\frac{dv_{Cf}(t)}{dt} = \frac{i_{Lf}(t)}{C_f} - \frac{v_{cf}(t)}{RC_f}\right\}\left\{\frac{di_{Lf}(t)}{dt} = \frac{V_{in}-v_{cf}(t)}{L_f}\right\} \quad (1)$$

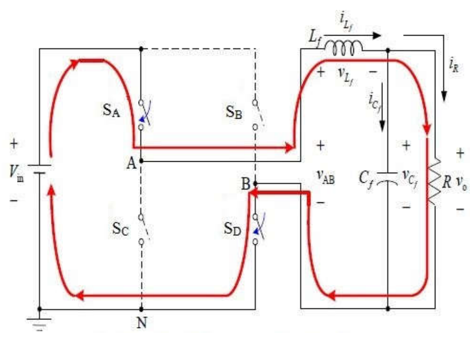

Fig.1. Equivalent Circuit when S_A and S_D are switched ON

Second Topology: Based on SPWM, the system can produce a negative half sine wave for the load when S_B and S_C are turned on (u= 0). The equivalent circuit is shown in Fig.2. The state-space equation is expressed using the circuit topology as follows:

$$\left\{\frac{dv_{Cf}(t)}{dt} = \frac{i_{Lf}(t)}{C_f} - \frac{v_{cf}(t)}{RC_f}\right\}\left\{\frac{di_{Lf}(t)}{dt} = \frac{-V_{in}-v_{cf}(t)}{L_f}\right\} \quad (2)$$

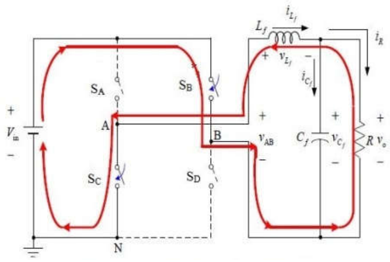

Fig.2. Equivalent Circuit when S_B and S_C are switched ON

Equations (1) and (2) are combined into the following equation with the controlled variable u at 0 and 1.

$$\begin{bmatrix} \frac{di_{Lf}(t)}{dt} \\ \frac{dv_{Cf}(t)}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{L_f} \\ \frac{1}{C_f} & -\frac{1}{RC_f} \end{bmatrix} \begin{bmatrix} iL_f\,(t) \\ vC_f(t) \end{bmatrix} + \begin{bmatrix} \frac{V_{in}}{L_f} \\ 0 \end{bmatrix} (2u-1) \quad (3)$$

Where,

- U - Control Variable
- L_f - Filter inductance
- C_f - Filter Capacitance
- R - Load resistance
- V_{in} - Dc input Voltage

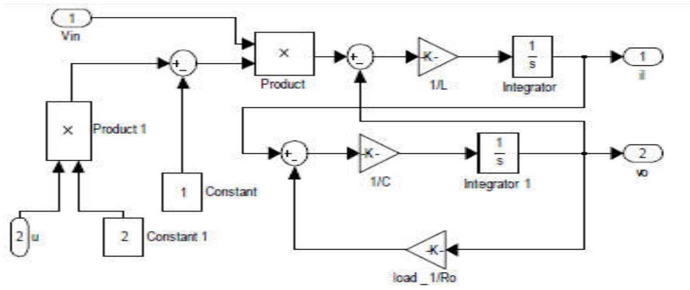

Fig. 3. Simulink full bridge inverter model

BACTERIA FORAGING OPTIMIZATION ALGORITHM (BFOA)

The Bacterial Foraging Optimization Algorithm (BFOA), developed by Kevin Passino in 2002, is the latest addition to the group of optimization algorithms that take inspiration from nature. This group's application is the multi-optimal function optimization of an E. coli bacterial swarm's foraging strategy. Bacteria look for nutrients as a way to get the most energy possible in a given amount of time. Each bacterium sends signals to other bacterium to communicate. The problem search space foraging theory, which assumes that animals seek for and collect nutrients in a way that maximizes their energy intake E per unit time T spent foraging, is the central concept of BFOA. As a result, they strive to optimize a function like E/T (or their long-term average rate of energy intake). Maximizing this function gives organisms more time to engage in other crucial behaviors, such as fighting, running, mating, reproducing, sleeping, or creating shelter, by giving them access to food sources [18-21].

After several generations, inefficient foraging techniques in BFOA are either eliminated or transformed into effective ones. The E. coli bacteria have a foraging strategy that is controlled by four processes, as listed below, and they are found in our intestines (the long tube in our body that transports food from our stomach to the location where it leaves our body).

A. Chemotaxis

Chemotaxis Process accomplished by swimming and flipping. Each bacterium determines throughout its whole existence whether to travel in a predetermined direction (swimming) or a completely different one (tumbling) based on the rotation of its flagella.

B. Swarming

The bacterium should always try to attract more bacteria once it has found the best route to the meal in order for them to get there more quickly. Bacteria that are swarming gather into groups and travel in concentric patterns with a high bacterial density.

C. Reproduction

The healthiest bacteria can split into other bacteria that are situated nearby while the least healthy bacteria perish. As a result, the bacterial population is stable.

D. Elimination and Dispersal

It is possible that a population of bacteria living in the area experiences a shift in their way of life, either gradually as a result of nutrient consumption or suddenly as a result of another factor. The bacteria in a location can all be killed or dispersed by certain events. They may have the impact of halting the chemotactic progression, but they may also help it because dispersal may bring bacteria close to nutritious food sources. Elimination and dispersion aid in lowering the stagnation behavior, or being stuck in an early solution point or local optimum. This method is employed in grid computing optimization since natural evolution serves as their main source of inspiration. It is widely acknowledged as a contemporary candidate for distributed optimization and control as a global optimization method. Locating, handling, and consuming the food are likewise done using this technique. A bacteria can engage in either swimming or tumbling when foraging. The bacterium's orientation is altered by the tumble motion. The bacterium will move in its current direction while swimming, which is referred to as the chemotaxis step.

A bacteria moves through chemotaxis until it moves in the direction of a positive nutritional gradient. The best half of the population goes through reproduction after a set number of full swims, which eliminates the remaining population. An elimination-dispersion event is run in which some bacteria are randomly eliminated with a very small probability and new replacements are initialized at random positions throughout the search space in order to escape local optima. The update of the tumble direction during the chemotaxis loop is dictated by,

$$\emptyset(J+1) = W * \emptyset(j) + C1 * R1(P_{lbest} - P_{current}) + C1 * R1(P_{lbest} - P_{current}) \quad (4)$$

Where P_l *best* is the best position of each bacterial and *Pg best* is the global best bacterial.

Bacterial Foraging Based Optimization Algorithm pseudo-code

[Step 1] Initialization: Parameters setting,

- *p:* Dimension of the search space.
- *S:* The number of bacteria in the population
- *N*c: Chemotaxis steps.
- *N*s: Swimming length.
- *N*re: The number of reproduction steps.

- *N*ed: The number of elimination-dispersal events.
- *P*ed: Elimination-dispersal with probability.
- *P (j ; k ; l)* : *P (j ; k ; l)* = f _*i (j ; k ; l)* j *i* = 1, 2,……….. *S*
- Generate a random vector (j) which elements lie in [-1, 1].
- *C*1, *C*2, *R*1, *R*2, *w*: PSO parameters

[Step 2] Elimination Dispersal loop: *l* = *l* + 1.

[Step 3] Reproduction loop: *k* = *k* + 1.

[Step 4] Chemotaxis loop: *j* = *j* + 1.

[4.1] take a chemotaxis step for every bacterium (*i*).

[4.2] Compute fitness function: *J* (*i*; *j*; *k*; *l*), then let *Jlast*= *J* (*i*; *j*; *k*; *l*).

[4.3] Tumble: Let (j+1) = *w* (j) +*C*1_*R*1 (*Plbest-Pcurrent*) +*C*2 _ *R*2 _ (*Pgbest-Pcurrent*).

[4.4] Move: Let _*i*(*j* + 1; *k*; *l*) = _*i*(*j*; *k*; *l*)
+ *C*(*i*)_(*j*).

[4.5] Swim: Let *m* = 0;

While (*m* <*N*s)

- let *m* = *m* + 1;
- if *J*(*i*; *j*; *k*; *l*) <*Jlast*

Computer fitness function: *J* (*i*; *j*; *k*; *l*),

- Let *J*(*i*; *j* + 1; *k*; *l*) = *J*(*i*; *j* + 1; *k*; *l*)+
- *Jcc* (0(j+ 1; *k*; *l*); *P* (j+ 1; *k*; *l*)).

[4.6] Go to next bacterium.

[Step 5] If (j<*N*c), go to Step 4.

[Step 6] Reproduction: Computer the health of the bacterium *i* $j^{i}_{health} = \sum_{j=1}^{N+i} J(i,j,k.l)$ Sort bacteria and chemotaxis parameters are C (*i*) in order of ascending cost J_{health}. Bacteria with the highest J_{health} values die, the remaining bacteria reproduce.

[Step 7] If (*k* <*N*re), go to Step 3.

[Step 8] Elimination-dispersal: Eliminate and disperse bacteria with probability *P*ed.

[Step 9] If (*l* <*N*ed), go to Step 2.

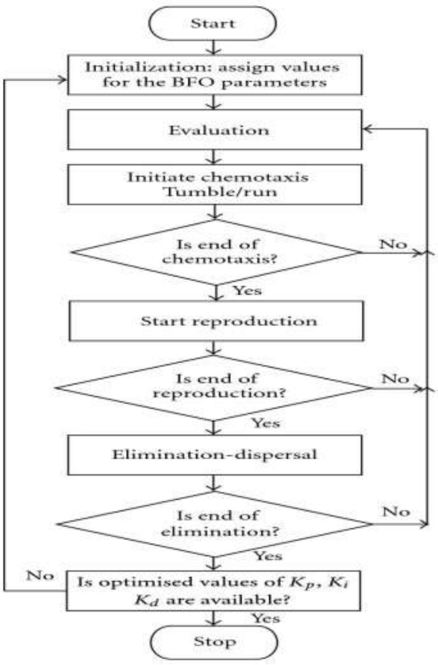

Fig.4 The BFOA flowchart MATLAB

SIMULATION:

To simulate with the SIMULINK model, the MATLAB/SIMULINK tool is used. To get the characteristic impedance, propagation constant, attenuation constant, and phase constant values, a MATLAB simulation is run based on the parameters of resistance, inductance, capacitance, and conductance. The following parameters will yield the desired result.

TABLE: 1 Full bridge voltage source Inverter specifications[2]

Circuit Parameters	Values
Input DC Voltage, V_{in}	15V
Load resistance, R_0	50 Ω
Filter Inductance, L_f	2 mH
Filter Capacitance, C_f	500 µF
Reference Signal, V_{ref}	5V Sine,50 Hz
Load waveform	Sine wave
Switching Frequency, f_s	7.69KHZ
PI Controller	K_p=19, K_i=7.1
PI Controller with BFO (Bacteria Foraging Optimization)Technique	K_p=17.2, K_i=9
Overload Capacity	110% Continues
Inverter Efficiency	>90%

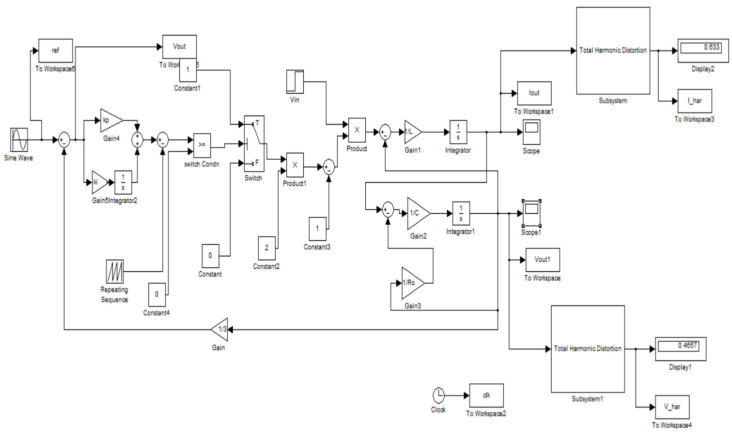

Fig.5 Block diagram of a PI controller in Simulink using the BFOA method

In Fig. 5, a Simulink block diagram for a UPS inverter with a PI controller is displayed. The addition of proportional and integral terms accelerates reaction time and reduces steady state inaccuracy. The output of the controller to the full bridge power inverter with optimal Kp and Ki values of 17.2 and 9.0, respectively. Simulink blocks are used to evaluate the percentage THD values of voltage and current harmonics.

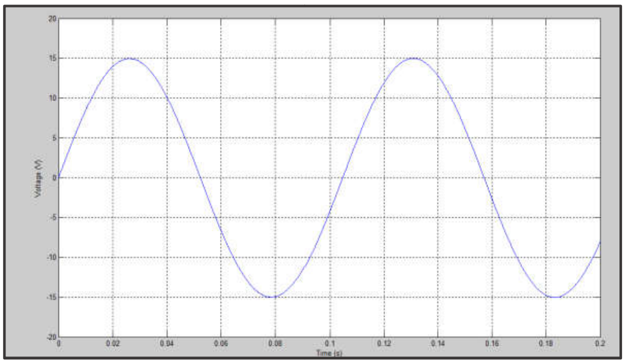

Fig.6 Voltage waveform using BFOA technique

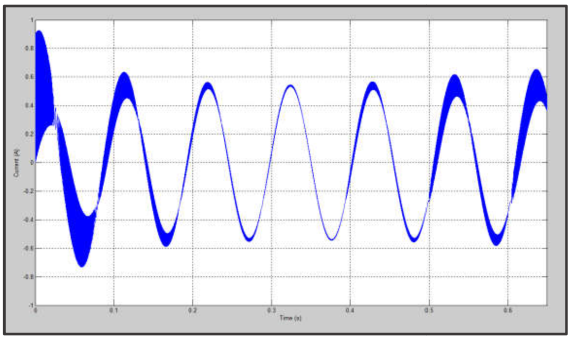

Fig.7 Current output waveform using BFOA technique

Plotted are the single phase inverter's response curves for voltage and current harmonics. Figure 6 depicts the output voltage waveforms for BFO algorithms generated by Simulink. In Figure 7, the output current waveforms employing BFO are displayed. For BFOA, there are no overshoots and the output voltage magnitude remains constant. For BFO algorithms, the output waveform of the current overshoots. In the instance of the BFO algorithm, the controller works well and reduces overshoots, causing the waveform to stabilize and exhibit less distortion.

EXPERIMENTAL VERIFICATION

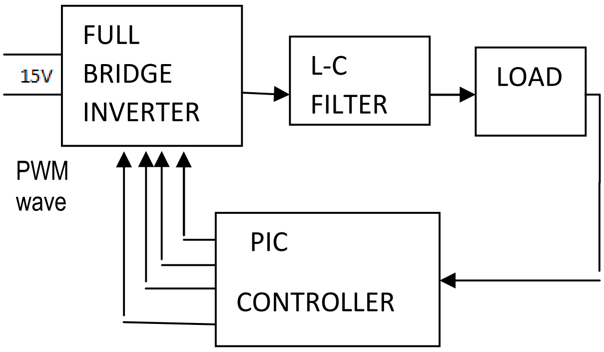

Fig.8. Block diagram of the proposed Full bridge VSI system

Fig.9. Hardware setup

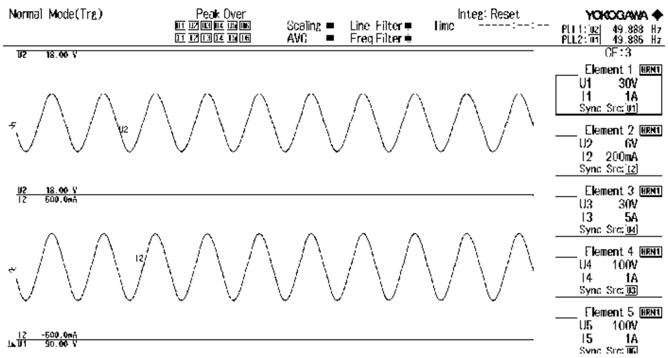

Fig.10 Hardware results using BFO Techniques (a) Voltage across Load (b) Current across Load

The block diagram of the hardware setup is shown in Fig.9 .The Micro-4011 trainer consists of Processor section, DAC section, ADC section, Display section, etc. [22]. A driver circuit uses the PWM wave generated by the PIC microcontroller (PIC30F4011) to switch on and off the power device by sending the appropriate gate signals. A miniature 4MHZ Quartz Oscillator is used as the resonator. It is an electronic oscillator circuit that generates an electrical signal with a highly precise frequency charge by using the mechanical resonance of a vibrating crystal made of piezoelectric material. PIC is used to generate pulse width modulation (PWM) wave by comparing sine wave and oscillatory wave. It consists of totally 40 pins of which 33 pins are divided into five Ports and remaining pins are multiplexed with an alternate function for the peripheral features on the device. General purpose I/O pins can be Considered the simplest of Peripherals. They allow the PIC microcontroller to monitor and control other devices. The special features of PIC microcontroller includes Enhanced Flash Program memory, Data EEPROM memory, Self reprogrammable under software control, Power-on reset (POR), Power-up reset (PUR), Oscillator start-up, etc. The output voltage and current waveforms from the Inverter module is shown in Figs.10 (a) and Fig.10 (b).

Table 2 Results of Comparative Software and Hardware Performance

SI.NO	Algorithm	Total Harmonic Voltage Distortion (%THD $_V$)	Total Harmonic Current Distortion (%THD $_I$)
1	SIMULATION USING BFOA	0.6949	1.117
2	EXPERIMENT USING BFOA	1.2	1.6

CONCLUSION

The voltage-controlled single phase full-bridge inverter in this study uses the Bacteria Foraging Optimization Algorithm (BFOA) for harmonic reduction. The outcomes of the simulation and experimental validation demonstrate that, in accordance with IEEE standard 549-1992, the harmonics are significantly decreased in BFOA. Power factor enhancement and inverter efficiency improvement are also benefits of this effort. According to the simulation and experimental results shown above, the converter performs well in both steady-state and dynamic inverter circumstances for changing Line and Load.

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