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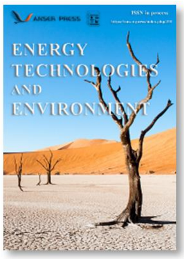

Optimal sizing and siting of single tunned passive filter based on jellyfish algorithm

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ABSTRACT

The presence of electrical harmonics in low voltage networks causes many problems for customers, the most important of which is the decrease in the power quality beyond the permissible limits, which leads to a decrease in voltage for long periods, a decrease in power factor and a large losses in the electrical network due to the deformation of the electric waveform of voltage and current. The aim of this paper is to design an optimal passive filter and its optimal location to suppress the harmonic distortion in the distribution system that results from nonlinear loads. This filter will use single objective functions and multi objective functions that will minimize the proposed filter cost, the real power losses, total harmonic distortion "THD" and individual harmonic distortion "IHD". This will be done under the equality constraint of power balance and some inequality constraints such as filter parameters limits, quality factor limits, voltage limits, harmonic distortion limits. The optimal passive filter parameters and location will be calculated using the modern optimization techniques such jellyfish optimization technique. IEEE 33 bus radial system will be used for demonstrating results obtained by the proposed method.

KEYWORDS

Power quality; passive filters; harmonic distortion; filter parameters

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1. Introduction

Electricity distribution networks encounter constantly changing generation demands and/or high load fluctuations from low to high, and vice versa. These problems are common for electricity distribution networks [1]. In recent years, due to widespread usage of nonlinear loads, the distortion of the waveform of current and voltage increases. As a result, voltage and current waveforms in a distribution or transmission system are hardly pure sinusoidal; instead, they include a mix of fundamental, harmonics, and other frequencies induced by transients. [2]. Loads with a nonlinear current-voltage characteristic inject a wide range of harmonics into the network, resulting in a deterioration of the power quality [3]. These harmonics can cause various problems, including power losses, resonance effects, telecommunication conflicts, malfunction of electric machines and decreasing of equipment's lifespan when existing harmonics exceed the IEEE 519 standard. As a consequence, harmonic mitigation is essential for power quality improvement.

According to comparison, the implementation of harmonic single tuned passive filters "STPF" into power systems is the straightest forward and widely adopted approach for minimizing THD since it is less expensive than other options [4]. These equipment are connected in shunt with the network and is consists of inductors (L), capacitors (C) and resistors (R) connected in series with each other so they act as an element with a low impedance, the current at the tuned frequency is forced to be absorbed by the filters to the earth[5]. The filter values are chosen depending on the needs of the system. [6].Location of passive single tuned filter very close to harmonic sources reduces transmission and distribution losses and has low investment risk, it also affords good power quality to other linear loads at system operating condition, and passive single tuned filter characteristics, size, and location determine impact of distribution system [7],[8]. In [9], an optimum design technique for passive filters to suppress important harmonics and increase power factor is presented based on the application of a mathematical model bat algorithm. In [10], based on the use of a genetic algorithm, passive filters are placed in a modified 33-bus distribution system to minimize harmonic distortions while keeping their levels within acceptable limits. In [11], to decrease THD and increase power factor, designing method of hybrid passive filter was presented using genetic optimization algorithm. In [12] based on the filter cost and losses, the design STPF is developed. The developed technique was used to develop a passive filter for two factories to use in order to simultaneously select the cable and filter size because there was confusion due to the presence of non-linear loads. In [13], [14] A method for compensating harmonics based on voltage and current harmonics caused by nonlinear loads is described. Based on voltage drop, voltage increase violation, tap movement rate of transformers, and curtailed power of PV units, the authors presented an optimal voltage management technique that takes into account the number of tap movements of transformers and the active power curtailment of PV units [15].

This paper aims to improve power quality of networks by suppressing harmonics using STPF. The proposed method will not improve power quality only, but also will choose the optimal location in where the filter will be located in the network and the optimal parameters of the filter that will achieve the objective functions within limits of some equality and inequality constraints which are filter parameters, quality factor, bus voltage magnitude, harmonic distortion for voltage and current and power balance. Suppression of harmonics here will be achieved by four single objective function which are minimizing filter cost, voltage harmonic distortion "VHD", power losses and current harmonic distortion "CHD". Jelly fish algorithm is used for finding a best location of the passive filter and its optimal parameters, giving the system a global benefit while also increasing its power quality. The suggested approach is simulated utilizing 33 bus radial distribution test feeders.

This work is subdivided into six sections, one of which being this introductory. In the second, optimal design and modeling of shunt STPF according to IEEE guide and standards are discussed. The problem constraints and objective functions description is presented in the third. In the fourth, the proposed technique is subjected to the use of the jelly fish algorithm. The fifth part describes the system and its results, while the last one presents the conclusions.

2. OPTIMAL design and modeling of proposed shunt STPF

Passive filters are used in power systems to suppress harmonic currents and reduce voltage distortion in sensitive sections of the network [16]. Harmonic filters are the most common solution to prevent the unwanted harmonic currents are prevented from flowing back into the power system by redirecting them through a low impedance shunt circuit, with a little percentage flowing back into the system. The main concept of the filter is visualized in Figure.1 [17]. While a harmonic source (such as a nonlinear load, distributed generation, renewable energy source, or power electronic device) injects harmonic currents into the electricity network, the filter helps to absorb the current flow at a tuned resonance frequency, reducing harmonic transmission and, as a result, system harmonic distortion.

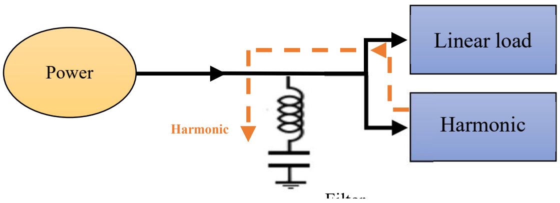

Figure 1. Basic principle of harmonic mitigation.

When a filter is joined in shunt, it only transmits the tuned harmonic current plus a fundamental current much less than that of the main network. Shunt filter is series-connection of inductors, capacitor and resistors and its impedance (Z_{fil}) can be expressed as:

$$Z_{fil} = R_{fil} + j\left(X_{l_{fil}} - X_{c_{fil}}\right) \tag{1}$$

Where Z_{fil}, R_{fil}, $X_{l_{fil}}$ and $\mathrm{X}_{c_{fil}}$ are the filter impedance, resistance, inductive and capacitive reactance respectively. Voltage and Current equation can be expressed as following [18]:-

$$V(t) = \sum_{h=1}^{\infty} v_h \, sin(\omega_h t + \emptyset_h) \tag{2}$$

$$I(t) = \sum_{h=1}^{\infty} i_h \, sin(\omega_h t + \emptyset_h) \tag{3}$$

where $V(t)$ and $I(t)$ are the total voltage and current including fundamental and harmonics, v_h and i_h are the hth voltage and current at different h harmonic orders, $\emptyset_h$ is the hth phase angle between current and voltage.

The Power converters are the direct source of harmonic currents in the AC power system. By analysing the 6 and 12 pulses converters, the orders of the AC harmonic frequencies will be in the q-pulses. Converters are clearly the multiples of the industrial frequency as:-

$$h = kq \pm 1 \tag{4}$$

Where k is an integer number (1,2,3,....etc.) and q is the number of converter pulses (6,12,18,24,....etc.). The resonance frequency is the frequency where the circuit will be in a resonance state, and it is generally defined in terms of harmonic order as following conditions:-

$$X_{l_{fil}} = X_{c_{fil}} \tag{5}$$

$$\omega_n \, l_{fil} = 1/\omega_n \, c_{fil} \tag{6}$$

$$\omega_n = n\omega_1 = 1/\sqrt{l_{fil} c_{fil}} \tag{7}$$

Where ω_n denotes the resonant frequency of the suggested filter, ω_1 is the system nominal frequency, l_{fil} and c_{fil} are suggested filter resonant inductance and capacitance, n is the resonant frequency number [19].

The filter parameters must be less than the resonance parameters. To achieve the intended performance of the optimum filter, the resistance, inductors, and capacitor values must be designed to perform at a certain harmonic frequency and decrease the associated harmonic distortion. STPF is used in a circuit to remove harmonic distortion by creating a resonant frequency that is lower than the harmonic frequency to be eliminated. At the required harmonic frequency, the filter circuit in the STPF is suppressed, resulting in a very low impedance and connecting the harmonic current to ground, preventing it from passing into the network [20]. Shunt filters can be designed for whatever rating is needed. To calculate the optimal parameters of the STPF, optimal capacitor $C_{opt_{fil}}$ value must be calculated first from the following equation [21]. Then using equation 7 the optimal inductance l_{fil} can be calculated.

$$C_{opt_{fil}} = \frac{1}{\omega_n}\left(\frac{\sum_1^h v_h i_h h \sin \emptyset_h}{\sum_1^h v_h^2 \, h^2}\right) \tag{8}$$

3. Description of problem formulation

The purpose of this paper is to improve power quality by adding the optimal STPF which is based on minimizing the suggested filter cost " $F1$", losses "$F2$", VHD " $F3$ "and CHD "F4". All the preview functions will be used as a single function and then will be used as a multifunction objective function to choose the best filter values and the best location of it within limits of some constrains. The presented objective functions will be evaluated by the Jelly Fish optimization technique accordance to the IEEE Std_519 restrictions and recommended standards [22].

3.1. The objective function

3.1.1. Minimizing the proposed filter cost " $F1$"

The greatest challenge of filter design is to minimize the total cost of the filter parameter. The most expensive parameter of any fitter is the capacitor [23]. The total proposed filter costs objective function can be explained by[24]:-

$$F1 = Min\ Cost_{filt} = Min\left[B_1 R + B_2 X_{l_{fil}} + B_3 X_{c_{fil}}\right] \tag{9}$$

$$B_1 = 18185.161 \times 10^3 \left[i_1^2 + \sum_{l=2}^{h} i_l^2\right] \tag{10}$$

$$B_2 = 7274067.603 \left[i_1^2 + \sum_{l=2}^{h} i_l^2/l\right] \tag{11}$$

$$B_3 = 7274067.603 \left[i_1^2 + \sum_{l=2}^{h} l \times i_l^2\right] \tag{12}$$

3.1.2. Minimizing Power Losses " $F2$"

The real power losses at a network's fundamental frequency are computed using standard fundamental power flow and are stated as follows:

$$F2 = Min\ P_{Losses} = Min \sum_{l=1}^{h} \sum_{i=1}^{N_b} i_i^2 R_i \tag{13}$$

Where N_b is the number of network branches, P_{Losses} is the active power loss described in [25].

3.1.3. Minimizing VHD " $F3$"

When considering voltage harmonics, two significant variables, $\mathrm{THD_v}$ and $\mathrm{IHD_v}$, must be included in the objective function. To decrease voltage harmonic distortion of the system, the following equation should be used:

$$Min\ THD_v = Min\left((1/|v_{1i}|)\sqrt{\sum_{h_n=2}^{h} \left|v_{h_n i}\right|^2} \right) \tag{14}$$

$$Min\ IHD_v = Min\left[v_{h_n i}/|v_{1i}|\right] \tag{15}$$

Where v_{1i} is the fundamental bus voltage, h_n is the harmonic order, $v_{h_n i}$ is the harmonic order voltage at bus i

3.1.4. Minimizing CHD " $F4$"

As considering current harmonics, two major issues including $\mathrm{THD_v}$ and $\mathrm{IHD_v}$ must be added in objective function. To minimize current harmonic distortion of the system, the following equations should be used:

$$Min\ THD_i = Min\left((1/|i_{1i}|)\sqrt{\sum_{h_n=2}^{h} \left|i_{h_n i}\right|^2} \right) \tag{16}$$

$$Min\ IHD_i = Min\left[i_{h_n i}/|i_{1i}|\right] \tag{17}$$

Where i_{1i} is the fundamental bus current, h_n is the harmonic order, $i_{h_n i}$ is the harmonic order current at bus i

3.1.5. Multi objective function "F"

Finally, the multi-objective function of the problem under consideration is introduced as follows:

$$F = a_1 F1 + a_2 F2 + a_3 F3 + a_4 F4 \tag{18}$$

In this research, a weighted technique is used to determine the objective function value of each recommended solution to a problem. As a result, the four factors a_1, a_2, a_3 and a_4, are constrained by

$$a_1 + a_2 + a_3 + a_4 = 1\ and\ 0 \leq a_1, a_2, a_3, a_4 \leq 1 \tag{19}$$

3.2. Problem Constraints

The previews objective functions must be calculated under the following constrained:-

3.2.1. Power balance constraints

$$\sum_{i=1}^{n_g} P_{g_i} = \sum_{i=1}^{n_{load}} P_{load_i} + \sum_{i=1}^{n_{loss}} P_{loss_i} \tag{20}$$

$$\sum_{i=1}^{n_g} Q_{g_i} = \sum_{i=1}^{n_{load}} Q_{load_i} + \sum_{i=1}^{n_{loss}} Q_{loss_i} \tag{21}$$

3.2.2. Filter parameter limits

$$X_l^{min} \leq X_{l_{fil}} \leq X_l^{max} \tag{22}$$

$$X_c^{min} \leq X_{c_{fil}} \leq X_c^{max} \tag{23}$$

$$R^{min} \leq R_{fil} \leq R^{max} \tag{24}$$

Where X_l^{min},X_l^{max},X_c^{min},X_c^{max}, R^{min} and $R^{max}$are the limits of inductive reactance, capacitive reactance and impedance respectively.

3.2.3. Quality factor constrains

$$Q_{factor}^{min} \leq Q_{factor} \leq Q_{factor}^{max} \tag{25}$$

Where Q_{factor}^{min} and Q_{factor}^{max} are the limits of power quality factor.

3.2.4. Voltage limitations in all network buses

$$V_{min} \leq V_i \leq V_{max} \tag{26}$$

Where V_{min} and V_{max} are the voltage limits from 0.95 Pu to 1.05 Pu respectively.

3.2.5. Harmonic distortion limits

By IEEE Std. 519, THD_v, and IHD_v should not be exceeded 5% and 3%, respectively, THD_i and IHD_i should not exceed 4% and 5%, respectively.

$$THD_v \leq THD_{v_{max}} \tag{27}$$

$$IHD_v \leq IHD_{v_{max}} \tag{28}$$

$$THD_i \leq THD_{i_{max}} \tag{29}$$

$$IHD_i \leq IHD_{i_{max}} \tag{30}$$

Where $\mathrm{THD}_{v_{max}}$,$\mathrm{IHD}_{v_{max}}$,$\mathrm{THD}_{i_{max}}$ and $\mathrm{IHD}_{i_{max}}$are the maximum limits of $\mathrm{THD_V}$, $\mathrm{IHD_V}$, THD_i and $\mathrm{IHD_i}$ respectively.

4. Jellyfish optimization technique

Because of the critical necessity of inserting a STPF into distribution systems, numerous methods have been developed to manage optimization problems while taking into account the various objective functions and all distribution power network constraints. In this paper, single tuned filter limits the presence of harmonics in a radial distribution system with a large number of nonlinear loads. They can play a significant electric component in decreasing total power loss, improving

the voltage profile, and keeping voltage and current harmonic distortion within an acceptable range by installing and establishing the ideal placement as well as suitable size of single tuned filter units. Algorithms for optimization method techniques, such as jellyfish [26], try to discover the best solution to a given optimization issue by reducing or maximising a specified objective fitness function. Jellyfish optimization technique is considered one of the recent optimization techniques which are used with single objective and multi-objective optimization problems. This technique, along with each jellyfish's natural motions within the swarm and the following ocean current to produce jellyfish blooms, has enabled these species to act nearly everywhere in the ocean. Jelly fish visits some sites in where the amount of food varies; thus, when food quantities are compared, the optimal site is found. Figure. 2 presents the steps of the algorithm.

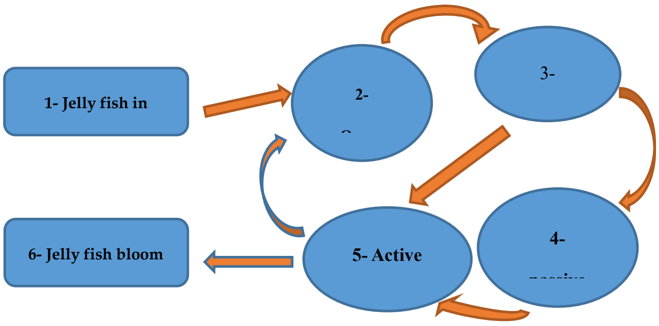

Figure 2. The behavior of jellyfish in the water.

Three idealised rules underpin the proposed optimization technique

Jellyfish either follow the ocean current or move inside the swarm, and the shifting between these modes of movement is controlled by a time control mechanism.

Jellyfish move in the ocean in searching for food. Locations where the available quantity of food is greater attracts more jelly fish.

The quantity of food found is determined by the location and its corresponding objective function.

The first population of jellyfish swarm is formed according to equation 33 then jellyfish moves around their own location and this update will be formed according to equation 34

$$M_k(t) = M_{min} + rand(M_{max} - M_{min}).\, k = 1. \dots . N^{pop} \tag{31}$$

$$M_k(t+1) = M_k(t) + \gamma \times rand(0.1) \times (M_{max} - M_{min}) \tag{32}$$

where M_{max} and M_{min} are the bounds of all decision variables in each considered solution, respectively; $\gamma > 0$ is a motion coefficient that is proportional to the length of motion around the jellyfish's sites. When the quantity of food at the selected first jellyfish's position surpasses that at the second jellyfish's location, the latter travels toward the former; if the amount of food accessible to the selected second jellyfish is less than that available to the first jellyfish of interest, it travels immediately away from it. As a result, each jellyfish "solution" goes in the best direction to obtain food in a swarm.

Figure 2 illustrates and describes in full the entire calculation process of utilizing the jellyfish optimization approach to determine the placement and size of all installed STPF units in distribution power network.

Flowchart describes the calculation process steps as shown in figure 3.

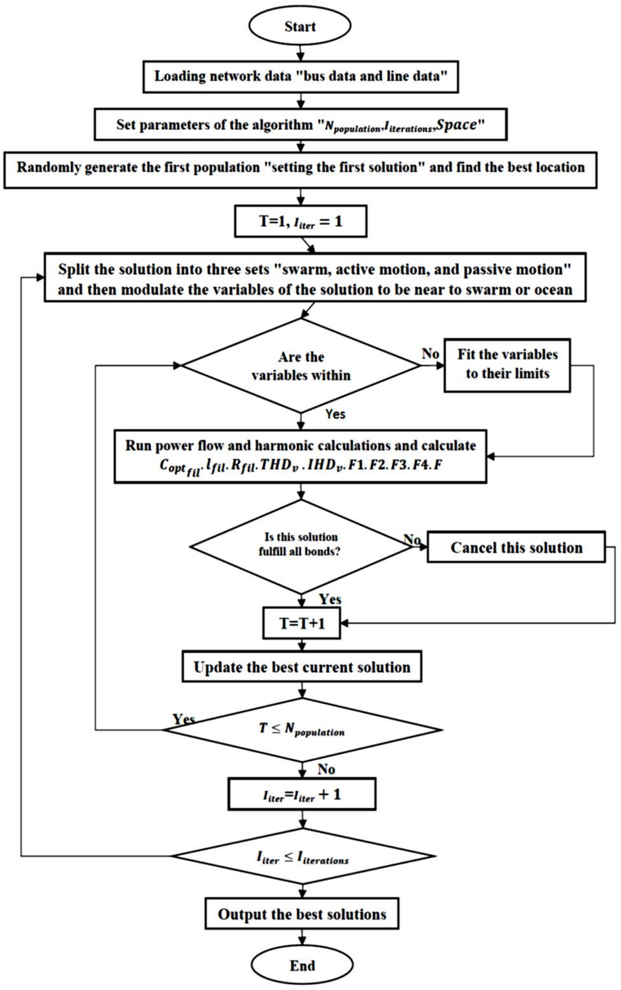

Figure 3. Flowchart of JF algorithm for determining the parameters and location of STF.

5. Results and System description

5.1. System description

The previews described objective functions will be applied to IEEE 33-bus distribution power network to achieve IEEE Std. 519 standers to keep voltage of all buses within the accepted limits. The data of the system is taken from [14]. In this section, for producing nonlinear loads, we inject five harmonic sources "HS" flow simultaneously to six loads located at buses 2, 11, 17, 22, 25 and 29 as shown in figure 4. Analysis of magnitude and angle of the five harmonic sources flows such as order, magnitude as well as angle are shown in Table 1 and are taken from [27].

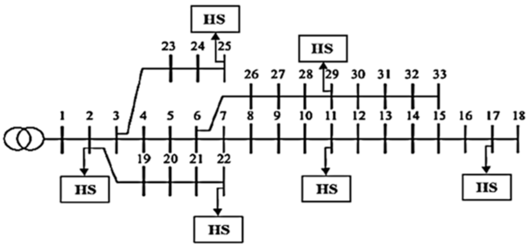

Figure. 4. IEEE 33-bus distribution network with six harmonic sources.

Table 1. Harmonic analysis of the five harmonic sources injected from loads in distribution power networks.

Harmonic order	Magnitude	Angle
5	0.766	28.5
7	0.63	-178
11	0.25	-61.5
13	0.128	82
17	0.073	-255

Injecting the five harmonic on the distribution system had a bad effect, of course, in the form of both voltage and current waves at these buses. Now, in order to improve the power quality at all network, a number of optimal filters are designed and presented in the next section. Each of these filters may be connected individually at the optimal location to improve power quality and make voltage and current in limits. Taking the total initial number of jellyfishes equal to 150, jellyfish optimization technique is implemented in MATLAB software using m-file code and the iteration numbers is 50. The proposed method is applied according to two scenarios studied as following:-

Scenario 1 :-Optimal single tuned filter parameters located at bus 1

Scenario 2 :-Optimal location and parameters of single tuned filter for three filters determined by optimization technique [28].

5.2. Results

5.2.1. Results of scenario 1

The results of applying jelly fish optimization technique in the previews distribution system with a fixed single tuned filter located at bus 1 is shown in table 2.

Figures 5, 6 show the harmonic analysis of the distorted voltage and current waveforms respectively at buses 2, 11, 17,22,25,29 before and after locating the optimal filter.

Figures explained that putting an optimal filter significantly from the existing network distortion due to the presence of harmonics and this more evident in the figures from 7,8 that illustrate the deformation waves of voltage and current before and after placing the filter at bus 1.

Inserting the single tuned filter at bus 1 reduced the harmonic values by about a third. Also, locating this filter at bus 1 led to significant improvement in the shape of the voltage and current waves.

Comparing the results in this paper with similar results in paper 25 file and found that the results of $\mathrm{THD}_v.\mathrm{THD}_i.\mathrm{IHD}_v.\mathrm{IHD}_i$ for this paper is better than the results in paper 25.

5.2.2. Results of scenario 2

Applying jelly fish optimization technique to determine the optimal location of filters, the results show that the optimal location will be at bus 2, 12, 23 and these results are shown in table 3. Figures 9, 10 show the harmonic analysis of the distorted voltage and current waveforms respectively at buses 2, 11, 17,22,25,29.

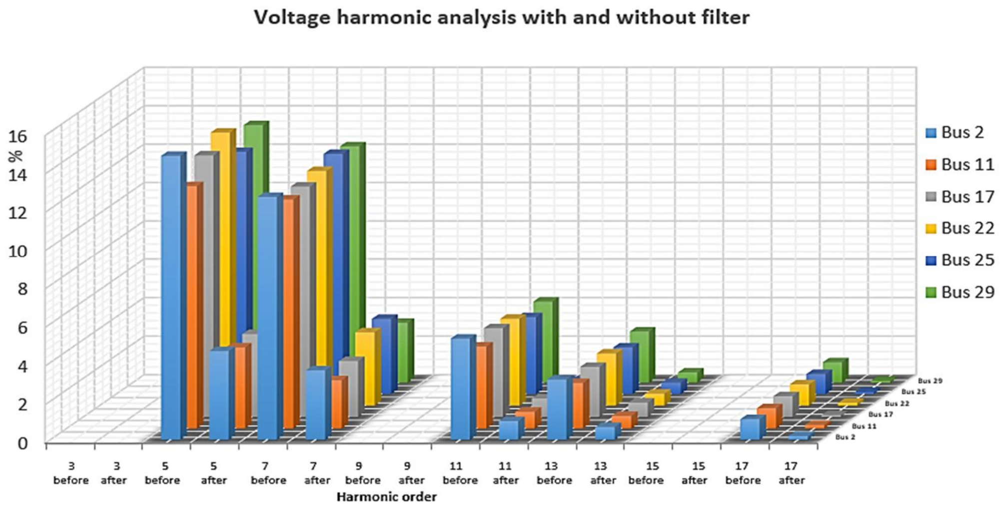

Figure 5. Voltage harmonic analysis before and after using one filter at bus 1.

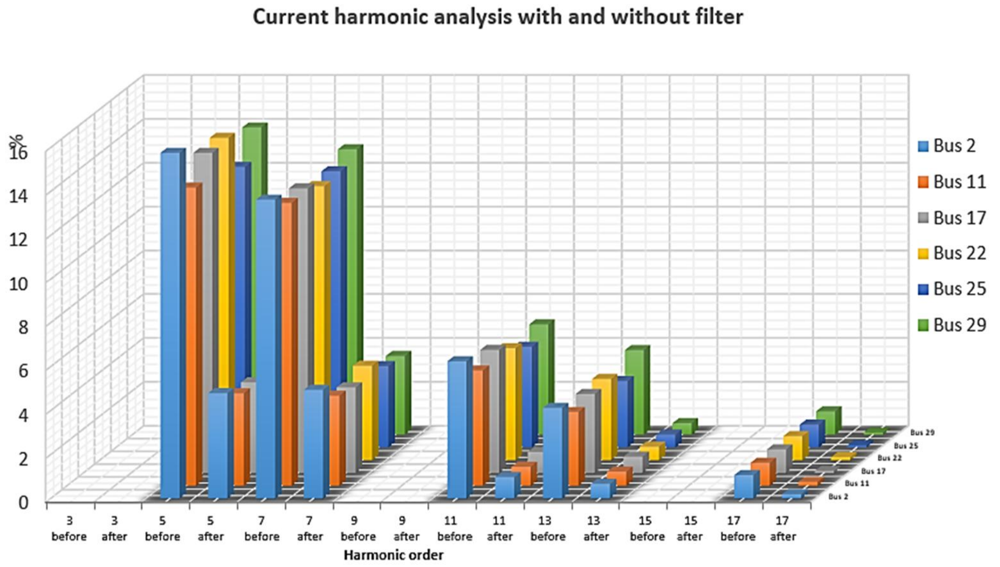

Figure 6. Current harmonic analysis before and after using one filter at bus 1.

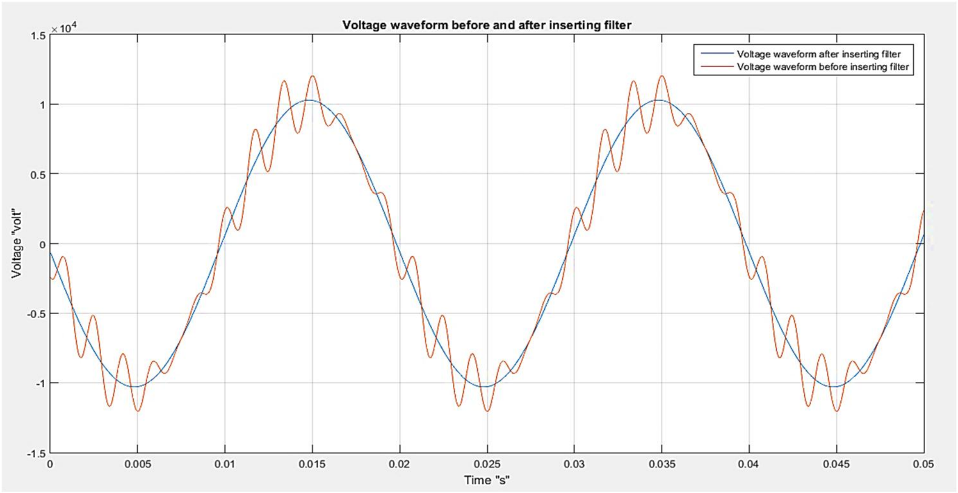

Figure 7. Voltage waveform at bus 2 with and without filter.

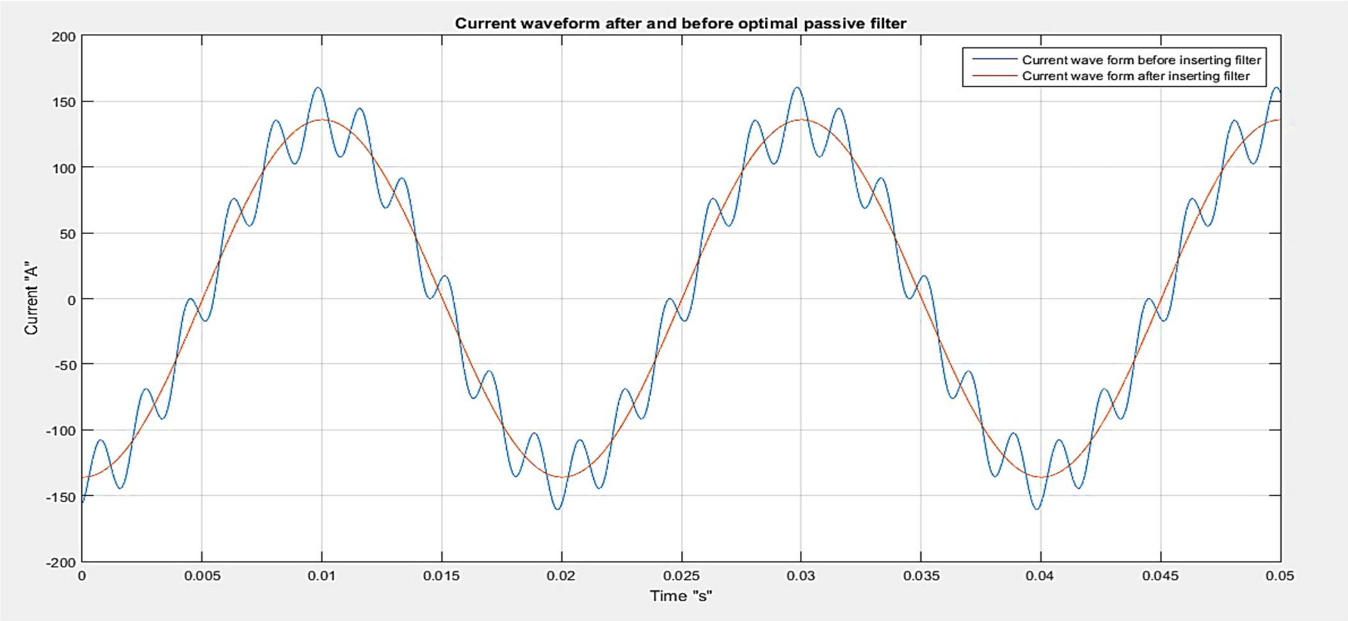

Figure 8. Current waveform at bus 2 with and without filter.

Table 2. Optimal filter parameters and filter cost after applying scenario 1.

		with filter				
Results of scenario 1	without filter	multi-objective function	single objective function			
		F	F1	F2	F3	F4
$\boldsymbol{Cost_{filt}}$ *"\$"*	---	4009.25	3804.56	4589.32	4367.75	4734.58
$\boldsymbol{Q_{factor}}$	---	37.68	39.5	39.2	37.2	37.5
Max and Min THD_v *%*	9.033, 4.52	3.355, 0.073	3.665, 0.083	3.752, 0.0653	2.98, 0.043	3.205, 0.052
Max and Min IHD_v *%*	3.9135, 7.52	2.5535, 0.054	2.5535, 0.054	2.5535, 0.054	2.896, 0.014	2.5535, 0.054
Max and Min THD_i *%*	23.5, 6.98	2.8, 0.0125	2.8, 0.0125	2.8, 0.0125	2.8, 0.0125	2.8, 0.0125
Max and Min IHD_i *%*	7.62, 4.63	1.87, 0.0478	1.87, 0.0478	1.87, 0.0478	1.87, 0.0478	1.87, 0.0478
$\boldsymbol{P_{loss}}$ *"MW"*	0.02037	0.0115	0.01578	0.00965	0.0147	0.0189
$\boldsymbol{R_{fil}}$ *"Ω"*	---	0.0654	0.0634	0.0569	0.0665	0.0712
$\boldsymbol{l_{fil}}$ *"mH"*	---	0.0036	0.003	0.0069	0.0076	0.00469
$\boldsymbol{C_{fil}}$ "$\boldsymbol{\mu f}$"	---	125.47	120.037	122.627	123.48	126.407
$\boldsymbol{Q_c}$ "$\boldsymbol{MVAR}$"	---	2.106	2.236	2.136	2.725	2.789
Location of filters	---	One filter located at Bus 1				

The results show that the second scenario is more expensive than the first one by 30% and the two scenarios achieves the limits, so choosing the first scenario is the optimal solution. Also, it shows that THD_v for the second scenario is lower than for first by 50%, IHD_v decreased by 63%, THD_i decreased by 43%, IHD_i decreased by 31%, but the two results are within limits. In addition, the power loss decreased in scenario one than scenario two by 71%.

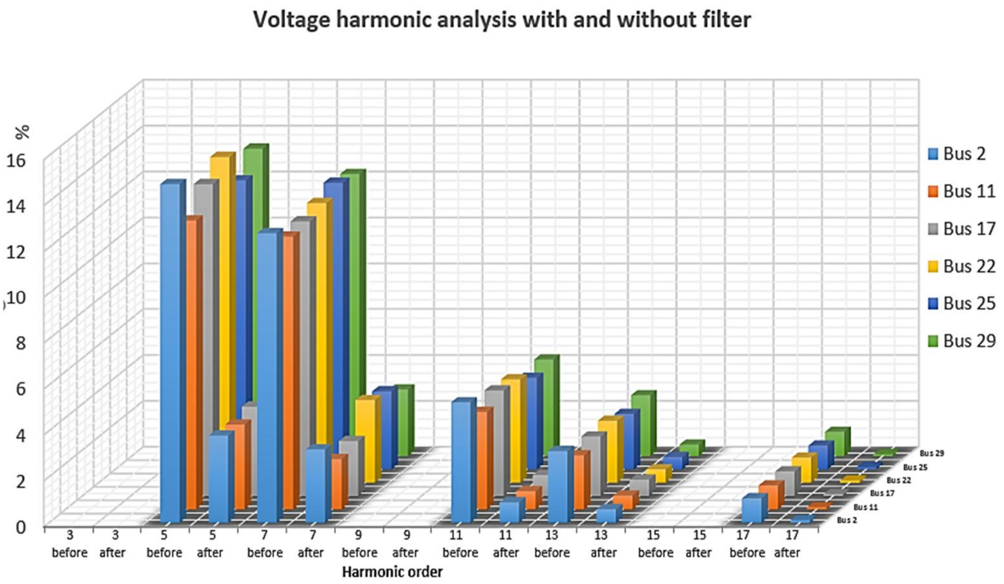

Figure 8. Voltage harmonic analysis before and after using three filters.

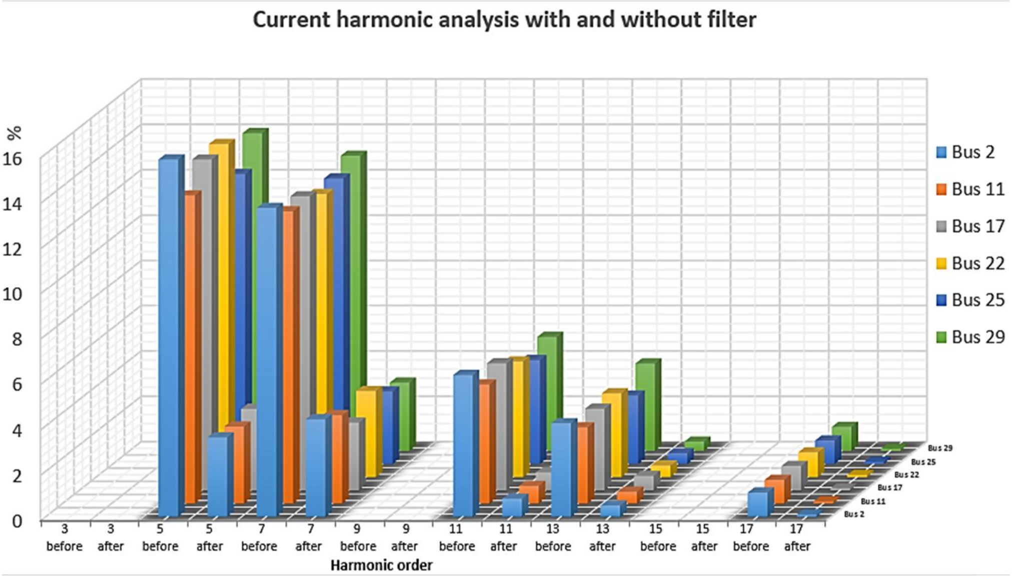

Figure 9. Current harmonic analysis before and after using three filters.

6. Conclusion

In this paper, a STPF was designed for distribution system to minimize losses cost, the real power losses, THD and individual harmonic distortion based on power balance, filter parameters, quality factor, voltage and harmonic distortion limits. This was done using two scenarios, the first using only one optimal STPF size at bus 1 and the second was choosing the best location and size of three STPF using jellyfish optimization technique. A comparison between the two scenarios was done and shows that if the aim of the problem is minimizing the filter cost, so scenario 1 will be the optimal solution. But, if the aim was improving the power quality, so second scenario will be the optimal solution. The two scenarios are suitable to be applied to distribution system, but the first is a good choice for minimizing the filter cost within limits of power quality.

This design was applied to IEEE 33-bus distribution power network and the results shows that jelly fish optimization technique can solve like these problems.

Table 3. Optimal filter parameters and filter cost after applying scenario 2.

Results of scenario 2	Without filter	With filter										
		Multi-objective function			Single objective function							
		F			F1		F2		F3		F4	
$\boldsymbol{Cost_{filt}}$ "$"	---	1st	2015.4	5249.5	1852.4	4873.8	2136.3	5969.3	2369.5	6009	2256.4	5959.8
		2nd	1468.6		1485.6		1869.5		1854.2		1947.1	
		3rd	1765.8		1535.8		1963.5		1785.3		1756.3	
Max and Min THD_v *%*	9.033, 5.69	2.225, 0.085			2.325, 0.0985		2.425, 0.063		2.2, 0.047		2.565, 0.036	
Max and Min IHD_v *%*	3.9135, 7.54	1.564, 0.0127			1.64, 0.0327		1.658, 0.0158		1.5, 0.0258		1.598, 0.0112	
Max and Min THD_i *%*	23.5, 4.19	1.95, 0.0189			1.195, 0.0289		1.96, 0.0149		1.2, 0.0369		1.103, 0.0179	
Max and Min IHD_i *%*	7.62, 3.65	1.417, 0.0178			1.218, 0.0778		1.58, 0.0589		1.04, 0.0196		1.01, 0.0158	
$\boldsymbol{P_{loss}}$ *"MW"*	0.02037	0.0197			0.01995		0.0104		0.01954		0.01923	
$\boldsymbol{R_{fil}}$ *"Ω"*	---	1st filter	0.0256		0.0198		0.0145		0.0369		0.0345	
		2nd filter	0.0165		0.0147		0.1258		0.1698		0.1674	
		3rd filter	0.0033		0.0025		0.0014		0.0048		0.0078	
$\boldsymbol{l_{fil}}$ *"mH"*	---	1st filter	0.0125		0.0114		0.0105		0.0155		0.0189	
		2nd filter	0.00965		0.00905		0.009		0.0145		0.0198	
		3rd filter	0.0106		0.0096		0.0087		0.0025		0.0046	
$\boldsymbol{C_{fil}}$ "$\boldsymbol{\mu f}$"	---	1st filter	66.98		56.8		78.9		74.6		72.3	
		2nd filter	59.23		56.3		57.4		57.3		59.4	
		3rd filter	73.08		69.5		68.5		78.1		74.2	
$\boldsymbol{Q_c}$ "$\boldsymbol{MVAR}$"	---	2.86			3.69		3.91		3.65		3.94	
Location of filters	---	3 filters located at Buss 2,12,23										

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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