



Optimal Allocation of the Distributed Active Filters Based on Total Loss Reduction

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Abstract

With the dramatic growth of nonlinear loads, it is desired to improve active filters performance and enhance their capacity. One of the most favorable methods is applying distributed active filter system (DAFS) in which leads to minimizing the cost, weight & size. The main purpose of this paper is to determine the locations and sizes of distributed active filter system (DAFS) With emphasis on reducing losses. Minimizing the total losses can have a significant impact on reducing costs. Therefore, placement has been studied by total line losses & minimized loss allocation while satisfying harmonic voltages, total harmonic voltage distortions within IEEE-519 recommended limits. Finally, a typical 37-bus distribution system is selected to verify the validity of the proposed procedures.

Keywords: Distributed active filter system, Particle swarm optimization, optimal placement, Total harmonic distortion, Loss allocation, Loss reduction.

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1. Introduction

Within Power pollution drawn from nonlinear loads such as switching mode power supplies, commercial lighting, ovens, and adjustable speed drives results in the degradation of power quality in the distribution system. The non-sinusoidal balanced or unbalanced currents generate harmonics, reactive power, and excessive neutral current. Conventionally, passive filters have been used to eliminate current harmonics and increase the power factor. However, the use of passive filter has many disadvantages. Recently, active power filters have been widely studied for the compensation of harmonic and reactive currents in power systems [1]. Active filters are an up-to-date solution to power quality problems. These filters allow the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than the conventional approach (capacitors for power factor correction and passive filters to compensate for current harmonics)[2]. One of the most favourable methods for harmonic compensation in distribution networks with many harmonic sources is using

distributed active filter system (DAFS). The DAFS could control the harmonic levels in the presence of different harmonic sources and leads to minimizing the cost and increase of reliability [3, 4].

The installation of an APF in an appropriate place and proper size is one of the recent research topics. Regardless of any solution procedure, allocation and sizing of APFs are normally found based on optimization process in which various objective functions may be employed [3-19].

This paper provides power loss reduction as a solution to achieve the harmonic standard levels for all buses by Minimizing the number of filters, total losses and 2nd cost. Accordingly the placement of DAFS in distribution system has been considered and with providing a comprehensive approach using particle swarm optimization (PSO), a fitness function in order to achieve desired goal has been proposed. Finally, the proposed method on a 37-bus test system Will be analyzed and optimal size & number of filters To satisfy the above conditions will be obtained and Overall conclusions will be presented. The results

demonstrate the effectiveness and superiority of proposed method.

2. APF Model

The APF can be modeled as a current source as it is injecting harmonic currents to the system, the phasor presentation of each APF current in DAFS is shown by I_m^h which m indicates the bus number connected to and h is the order of harmonic, i.e. we have

$$I_m^h = I_m^{h,r} + j I_m^{h,i} \quad (1)$$

The indices, r and i , represent the real and imaginary parts, respectively. The RMS current of each APF is determined as follows:

$$I_m = \left[\sum_{h=2}^H \{ (I_m^{h,r})^2 + (I_m^{h,i})^2 \} \right]^{1/2} \quad (2)$$

Where, H is the maximum order of desired harmonics [3].

3. Implementation of the proposed algorithm

Placement of the DAFS problem is solved with three sets of variables as follows:

(a).The first variable is the location of DAFS, which is an $N \times H$ matrix.

(b).The second variable is the size of DAFS to compensate for the real component of injection current, which is $N \times H$ matrix.

(c).The third variable is the size of DAFS to compensate for the imaginary component injection current, which is $N \times H$ matrix

Initially, in order to calculate the magnitude the bus voltages, the load flow [20, 21] is done for the fundamental harmonic and the resulting values are given as input to the PSO program to calculate the total harmonic distortion.

Since in distribution system with nonlinear loads, usually the best place to install the filter is load bus with higher harmonic injection currents, in order to obtain fast convergence rates for an optimization method, the first half of the initial population for select a location to installation of DAFS is chosen through the bus with the highest injection current(buses with current amount more than 10% of current amount of bus with maximum injection current) and the other half of the population, is considered a random.

In continuing, with PSO program implementation, harmonic load flow is done and minimum objective function value obtained.

Programming is done inside a while loop and until the constraints are not met, number of filters is increased by one. Figure 1 show, the flowchart of the proposed algorithm.

Constraints and objective functions

Select the appropriate objective function plays an important role in the optimal placement of DAFS. Where minimizing the total losses can have significant impact in reducing costs, Therefore, total line losses can be considered as one of the major factors in the proposed objective function. Also injection current of each filter will cause to create losses in the distribution system, Thus minimizing losses caused by passing active filter injection current through distribution system lines, can be an effective factor in filters placement. Hence, minimum allocation of losses for each filter is considered as the other parameter of proposed objective function. More ever, in order to reduce the unwanted effects of harmonic distortions on the network, two of the constraints are focused on employing harmonic standards on voltage harmonic distortion and total harmonic distortion (THD) level in each bus is considered. Each of the factors are reviewed:

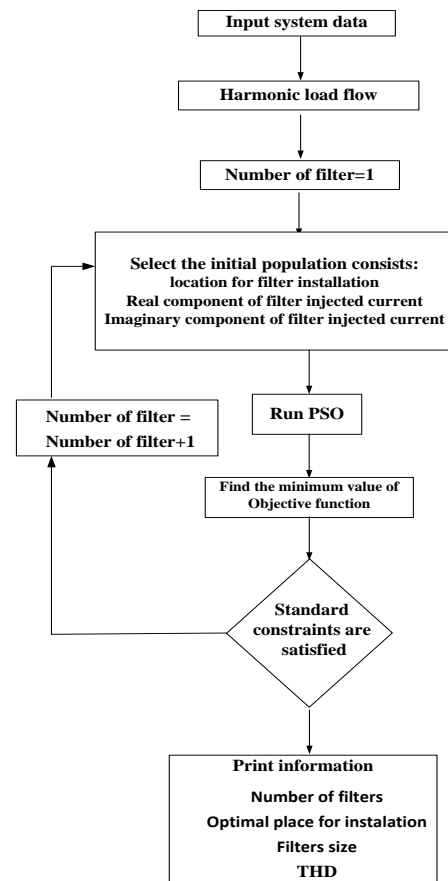


Fig. 1. Proposed algorithm flowchart for distributed active filters placement

A) Placement with minimizing line losses

Total harmonic losses in distribution system can be expressed as follows:

$$P_{loss} = \sum_{h=2}^{harmonicnumber} \sum_{i=1}^m r_i (I_i^h)^2 \tag{3}$$

$$= \sum_{h=2}^{harmonicnumber} \sum_{j=1}^m r_j \times \left\{ (I_j^{h,i})^2 + (I_j^{h,r})^2 \right\}$$

Where

m : The total number of branches in the distribution system

I_j^h : Current through the branch j at harmonic h .

i & j : represent the real and imaginary parts,

B) *Placement with a minimum allocation of losses for each filter*

Allocation of losses for each filter can be obtained as follows:

$$P_{lossfilter} = \sum_{h=2}^{harmonicnumber} \sum_{i=1}^m r_i (I_{i,1}^h + I_{i,2}^h + \dots + I_{i,N}^h)^2$$

$$= \sum_{h=2}^{harmonicnumber} \sum_{i=1}^m r_i \left((I_{i,1}^h)^2 + (I_{i,2}^h)^2 + \dots + (I_{i,N}^h)^2 \right. \tag{4}$$

$$\left. + 2I_{i,1}^h I_{i,2}^h + 2I_{i,1}^h I_{i,3}^h + \dots \right.$$

$$\left. + 2I_{i,N}^h I_{i,1}^h + \dots + 2I_{i,N}^h I_{i,N-1}^h \right)$$

Share of partnership for each filter from total losses can be obtained as follows

$$P_{filter} = \sum_{h=2}^{harmonicnumber} \sum_{i=1}^m \sum_{k=1}^N r_i \left((I_{i,k}^h)^2 + 2I_{i,k}^h \sum_{\substack{j=1 \\ j \neq k}}^N I_{i,j}^h \right) \tag{5}$$

Where

$I_{i,k}^h$: Injection current of k^{th} filter through the branch i at harmonic h

$I_{i,j}^h$: Injection current of j^{th} filter through the branch i at harmonic h

N : Number of filters

C) *THD constraint satisfaction*

The first goal in the placement of active filters in distribution network is to satisfy standard constraints of total voltage harmonic distortion rates of each node.

D) *Harmonic voltage constraint satisfaction*

The next goal in placement of active filters in distribution network is to satisfy standard constraints of voltage harmonic distortion rates of each harmonic for each node.

E) *Objective function*

Hence, the proposed objective function is as follows:

$$OF = A \times P_{loss} + B \times P_{lossfilter} \tag{6}$$

$$, THD < 5\% \ \& \ V_h / V_1 < 3\%$$

Where

P_{loss} : Total harmonic losses.

$P_{lossfilter}$: Allocation of losses for each filter.

And A, B are Coefficients of each of the factors.

V_h / V_1 : voltage harmonic distortion rates of harmonic h to main harmonic for each node.

(THD<5%): Effective factor for total harmonic distortion constraint satisfaction of each bus.

($V_h / V_1 < 3\%$): Effective factor for voltage harmonic distortion constraint satisfaction of each bus for different harmonic.

4. Numerical Results

To address the impact of the place of filters installation, suitable location and obtaining of minimal injected current of each filter, we will perform the studies on the sample 37-bus distributed network (Fig.2).

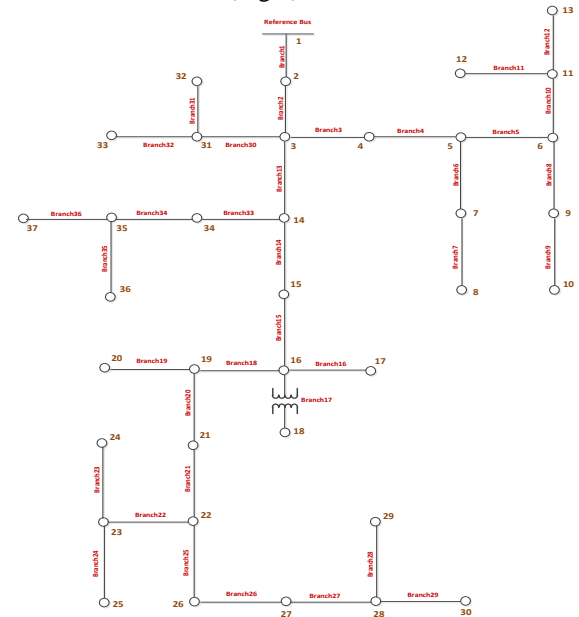


Fig. 2. 37-bus radial distribution network (IEEE 37 Node Test Feeder)

We do the location problem in order to achieve the THD lower than 5% in all buses and harmonic voltage lower than 3% for each harmonic in all buses.

A) *Placement with emphasis on the total losses reduction*

As the decrease of total losses will lead to the decrease of costs and other problems from losses, we address the problem to minimize the total losses in objective function and with emphasis on minimizing losses and the satisfying standard harmonic constriction on 37-bus radial network. The results from location are presented in Table 1.

Table.1.

Results from the distribution of harmonic lead after installation of filter to minimize the total losses.

Filter number	Bus no	Total losses	THD ave%	Filter size p.u
1	21	0.01	3.46	2.32
2	22,34	0.0077	3.66	1.7
3	6,16,26	0.0054	3	1.49
4	6,15,22,27	0.0051	2.98	1.26
No	-	0.034	10.47	0
		A=1 &	B=0	
Max Vh/VI	Number of Vh/VI>3%	Max THD	Number of THD>5%	
9.83	135	16.44	35	
		Total=333	Total=37	

By increasing the filter numbers, the amount of total losses would be decreased. In number of installed filters in distribution network is presented.

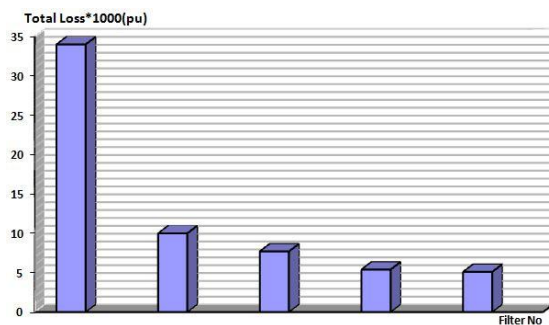


Fig. 3. The comparison of total losses based on filter numbers.

B) Placement with a minimum allocation of losses for each filter

Decrease of line losses from the appearance each filter in distribution network, can be an efficient factor to reduce the costs of making filter. Thus, to accomplish this purpose, we perform the problem of placement with emphasis to minimize the amount of line losses from the appearance of each filter in distribution network. The results from locating are presented in Table 2.

Table.2.

Results from harmonic load distribution after filter installation to minimize assigned losses of each filter

Filter number	Bus no	Total losses	THD ave%	Filter size p.u
1	21	0.012	3.67	2.16
2	15,26	0.011	3.79	1.54
3	14,19,27	0.0097	3.72	1.29
4	14,15,19,28	0.0084	3.67	1.16
No	-	0.034	7.29	0
		A=0 &	B=1	
Max Vh/VI	Number of Vh/VI>3%	Max THD	Number of THD>5%	
9.83	135	16.44	35	
		Total=333	Total=37	

The amount of effective current required for filters in order to satisfying standard harmonic constrictions in state of exerting assigned losses

factor in locating is less than state of exerting losses factor. Figure 4 indicate comparison the amount of effective injected current of filters with losses effect and with assignation losses.

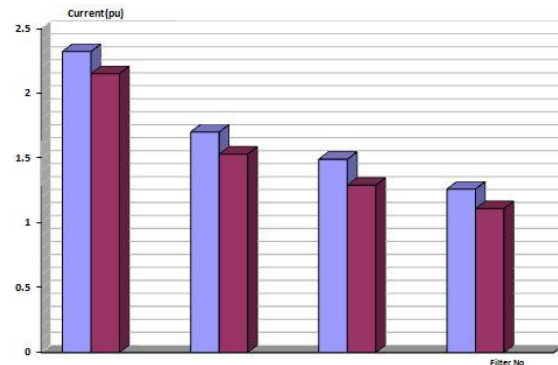


Fig. 4. The comparison of the value effective injected current of filters based on filter numbers for radial network with losses effect and with assignation losses

Likewise, the total losses comparison is presented in figure 5 in two states of locating with minimizing the total losses and locating with minimal assigned losses.

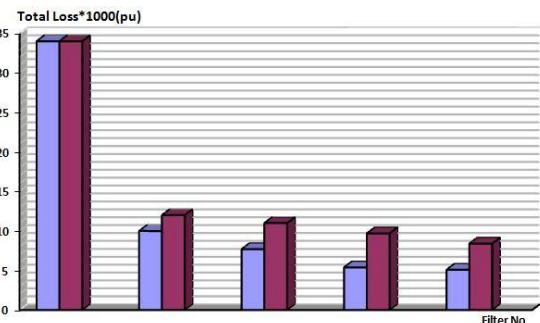


Fig.5. The total losses comparison in two state of locating with minimizing the total losses and locating with minimal assigned losses based on filter number

5. Discussion and Analysis

The effective size of active filter required to minimal assigned losses compared to minimizing the total losses is great, in a distribution network with limited harmonic resources; the buses of harmonic producer are the most suitable candidates to install the filters.

The select of installed filter number and their size is to some extent related to user purpose of performing filtering action, thus we can prefer sometimes the factor of filter number to the factor of minimal size of installed filter and used of two filters or more active filter with small sizes instead of one or more active filters at the same bus with greater size, obviously, this state would has its own difficulties including coordinating problem and etc.

Achieving to low line losses, would be feasible by increasing in number and size of filters,

thus, generating balance among these three factors can be performed based on economical conditions and considerations.

6. Conclusions

The main purpose of this paper is to determine size, location and appropriate number for distributed active filters being installed in power network. In this regard, with assessment of offered methods, it would be dealt with on offer to one comprehensive location algorithm by using PSO.

In the following, by implementing of above method on the on 37 radial bus network with spread harmonic leads, the capability of mentioned method has been examined to locate filter in network with abundant non-linear load. Finally, Comparison of values has been conducted and favourable results were obtained.

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