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# Power Quality Improvement in Radial Distribution System by Power Filter Using Differential Evolution Algorithm

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## ABSTRACT

This paper presents the power quality (PQ) improvement in radial distribution system (RDS) by placing active filter (AF). The harmonics is the cause of poor PQ. AF is used to reduce the harmonics injected by nonlinear load (NL) into RDS. The simulation is done on IEEE-69 bus system. The NL is connected in RDS. The THDv is calculated using harmonic load flow at all the buses of RDs. By proper placement of AF the cost of AF is reduced. To find the AF current which is required to limit the IEEE standards, differential algorithm (DE) is utilized. DE has found the minimum required AF current such that it limits the harmonics up to standard limit. Simulation results show the effectiveness of DE for improvement in power quality in RDS.

**Keywords:** DE, Harmonics, Power Quality, Radial Distribution System

## I. INTRODUCTION

Due to increase the use of power electronics equipments in day to day life it also increases the power quality (PQ) problems in distribution system (DS). The PQ problems are in terms of voltage or current. The nonlinear behaviour of power electronics equipments generates harmonics. When, the nonlinear equipment connects with the DS, this nonlinear load (NL) also injects the harmonics into the DS. The other loads which are already connected with the DS they may have trouble however they are linear. It means the NL injects harmonics into the DS and the harmonics propagates in the DS. Harmonics are harmful to the DS and other electrical equipments are connected with the DS. It may result in poor quality of voltage and current, disturb the operation of sensitive loads, loss in terms of electrical and revenue, mal operation of protective equipments, and heating of the equipments [1].

The solution of this problem is harmonic filters. Generally there are two types of harmonic filters are available. Passive harmonic filters and active harmonic filters. Passive harmonic filters are less costly but they may cause resonance in DS. Due to this for proper solution is active filter (AF). The cost of the AF is directly proportional to its current. It generates the harmonics equal to the NL but in opposite direction. Therefore at point of common coupling the AF nullify harmonics generated by NL.

As per IEEE standard, the limit of total harmonic distortion in terms of voltage (THDv) is 5% [2]. Therefore there is no need to mitigate all the harmonics. It means that all the buses of DS have THDv less than 5%. AF current is a major concern as cost is directly proportional to the current. The optimization algorithm is required to calculate the minimum current of AF to achieve the standard limit in DS. According to the No Free Lunch Theorem, there is always opportunity to use different algorithms for different problems. In this paper, the different evolution (DE) algorithm is coupled with harmonic load flow and used for finding the current of AF, such that the all the buses have THDv is less than 5% for considered radial distribution system (RDS).

The organization of this paper is as follows. In Section 2 (Methods and Material) is presented, in Section 3 (Result and Discussion) results are discussed, and, 4 (Conclusion) is the last part of paper.

## II. METHODS AND MATERIAL

As discussed previously, for the finding minimum current required by AF to get standard limit various optimization algorithms were utilized to solve the problem. The Genetic algorithm, particle swarm optimization, firefly algorithm, and music inspired algorithm [3, 4, 5, 6] were utilized. Here, to solve the problem, the DE is used as an optimization algorithm. It is an evolution based algorithm. It was proposed by Storn [7]. It has structure with mutation, crossover, and selection operators. The optimization process of DE is very similar to genetic algorithm. It is coupled with harmonic load flow (HLF) and is used for the finding minimum AF current.

In this paper, problem formulation is done in harmonics environment as formulated in [8]. The line resistances and inductances other parameters are formulated with harmonics. The AF is formulated as nonlinear load generator. The HLF is formulated as given in [9].

The main objective is to find the minimum AF current to reduce the harmonics such that each and every bus has THDv less than 5%. It expressed as below:

$$Objective_{function} = IAF_{Minimum} \qquad (1)$$

The Figure 1, show the process of obtaining the minimum AF current.

## III. RESULTS AND DISCUSSION

In this section, the results are obtained and discussed.

### A. System

In this paper, the IEEE- 69 bus test system is used with modification [10]. It is shown in Figure 2. There are two nonlinear loads connected at buses 27 and 35. The harmonic spectrum is used of six pulse converter with modification. The order of harmonic is 5 to 49. Two nonlinear loads are connected at end nodes of the system, so the effect of harmonic is more. There are 69 nodes, only two nodes have nonlinear loads, but all the buses are affected by these harmonics. The calculated THDv of all buses without AF of this harmonic polluted system is shown in Table 1.

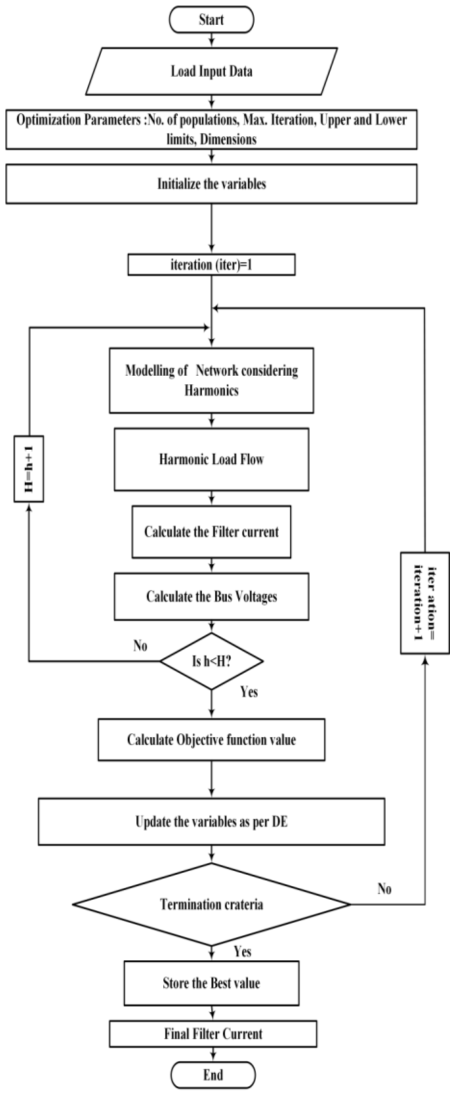


**Fig. 1** Flow chart

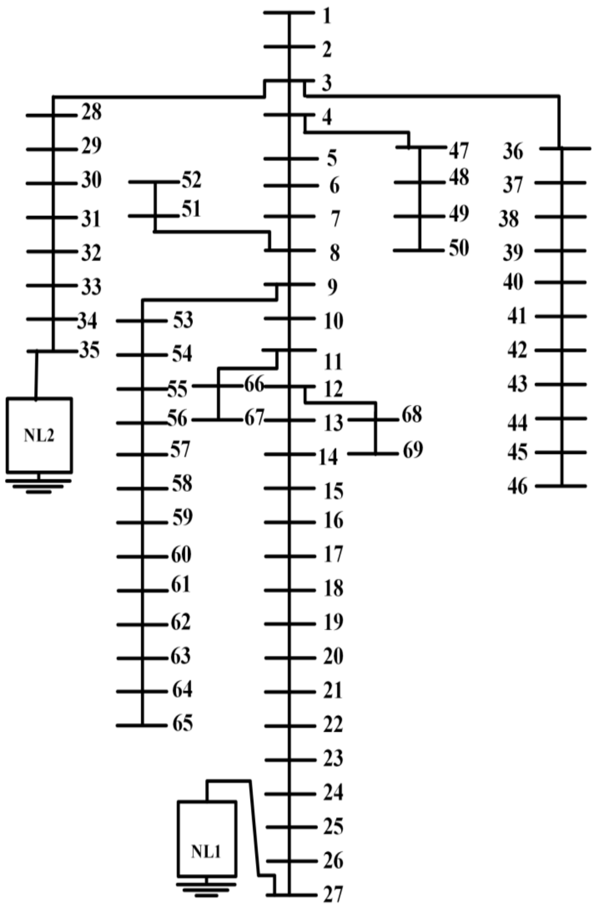


**Fig. 2** RDS with nonlinear load

Among the 68 buses (first bus is not included); thirteen buses have THDv more than 5%. It shows how the harmonics are propagated in entire RDS. Only two buses have nonlinear loads but all buses have THDv.

The highest THDv is 8.69%, and it is at bus 27. To limit these THDv within standard limit, harmonic filter/s is/are required. The NLs are connected at buses 27 and 35 so; AFs are allocated at buses 27 and 35.

To obtain the required AF current, DE optimization algorithm is applied here. The general optimization parameters like number of populations, maximum iteration are set 40 and 100 respectively. It is step by step simulated for considered test system as given in flowchart.

**B. Steps:**

Step 1: Load the data of test system, harmonic spectrum etc..

Step 2: Set the optimization parameters.

Step 3: Modelled the required inputs in harmonic environment.

Step 4: Run harmonic load flow

Step 5: Calculate the THDv with NL only.

Step 6: Connect the AF.

Step 7: Run the harmonic load flow including AF.

Step 8: Find the minimum AF current using DE optimization algorithm.

Step 9: Store the best value.

Step 10: Display the final minimum AF current.

**C. AF at bus 35:**

One AF is placed at bus 35; the Figure 3 shows the convergence curve of DE to obtain the minimum AF current. As shown in the figure, the algorithm is not converged to find the minimum AF current. It is observed that the bus 35 is not a proper placement of AF.

**D. AF at bus 27:**

Now, the AF is placed at bus 27, as shown in Figure 4, the algorithm is converged and obtained the minimum AF current for a given condition. The obtained value of AF current is 0.0142 p.u..

It shows the significance of place of AF. When, AF alone is placed at bus 35, it is not converged, means the AF at bus 35 is not suitable, while when AF is at placed at bus 27 the algorithm is converged.

It is observed from Figure 5, that after placing the AF at bus 27 the all buses of the system have THDv less than 5%. The bus 27 which has the highest THDv 8.69% without AF is now reduced to 5%. It is clearly observed from the figure. Similarly, the THDv at buses 15 to 26 are also reduced to standard limit. It shows the importance of AF in the improvement of PQ by reducing the THDv in the RDS.

**Table I. THDV AT ALL BUSES IN ABSENCE OF AF**

| Bus No. | THDv (%) | Bus No. | THDv (%) | Bus No. | THDv (%) | Bus No. | THDv (%) |
|---|---|---|---|---|---|---|---|
| 2 | 0.01 | 19 | **6.59** | 36 | 0.01 | 53 | 1.34 |
| 3 | 0.01 | 20 | **6.78** | 37 | 0.01 | 54 | 1.34 |
| 4 | 0.02 | 21 | **7.09** | 38 | 0.01 | 55 | 1.34 |
| 5 | 0.10 | 22 | **7.10** | 39 | 0.01 | 56 | 1.34 |
| 6 | 0.61 | 23 | **7.25** | 40 | 0.01 | 57 | 1.34 |
| 7 | 1.14 | 24 | **7.57** | 41 | 0.01 | 58 | 1.34 |
| 8 | 1.27 | 25 | **8.25** | 42 | 0.01 | 59 | 1.34 |
| 9 | 1.34 | 26 | **8.54** | 43 | 0.01 | 60 | 1.34 |
| 10 | 2.09 | 27 | **8.69** | 44 | 0.01 | 61 | 1.34 |
| 11 | 2.26 | 28 | 0.04 | 45 | 0.01 | 62 | 1.34 |
| 12 | 2.91 | 29 | 0.46 | 46 | 0.01 | 63 | 1.34 |
| 13 | 3.85 | 30 | 0.82 | 47 | 0.02 | 64 | 1.34 |
| 14 | 4.79 | 31 | 0.89 | 48 | 0.02 | 65 | 1.34 |
| 15 | **5.76** | 32 | 1.21 | 49 | 0.02 | 66 | 2.26 |
| 16 | **5.94** | 33 | 1.99 | 50 | 0.02 | 67 | 2.26 |
| 17 | **6.28** | 34 | 3.55 | 51 | 1.27 | 68 | 2.91 |
| 18 | **6.29** | 35 | 4.90 | 52 | 1.27 | 69 | 2.91 |

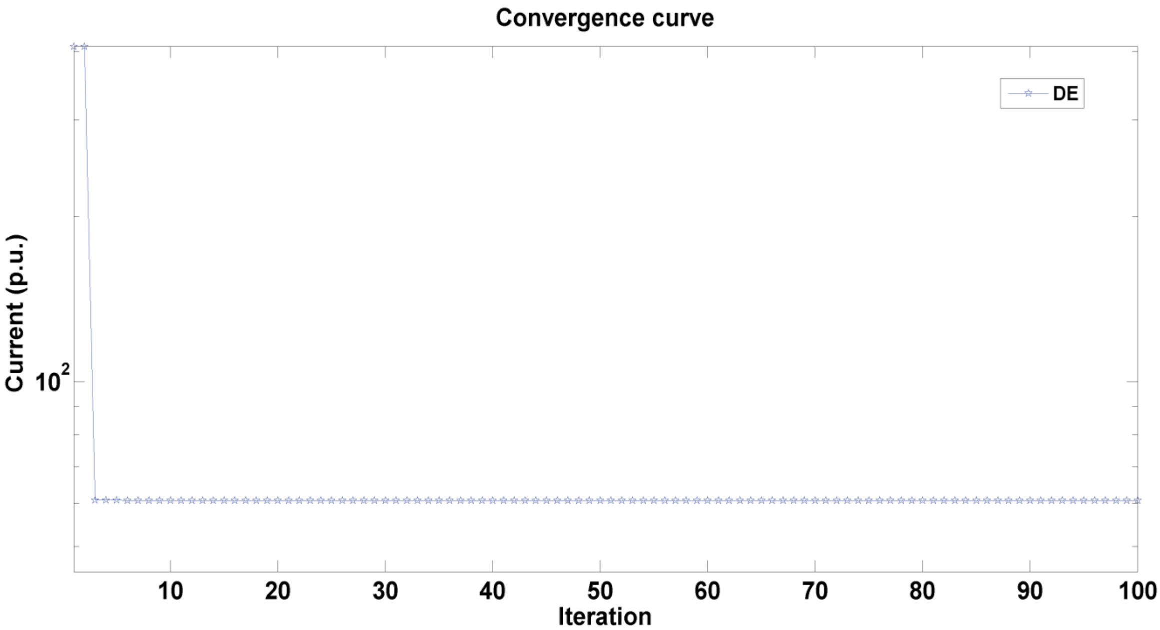


**Fig. 3** Convergence curve of optimization algorithm DE with AF at bus 35

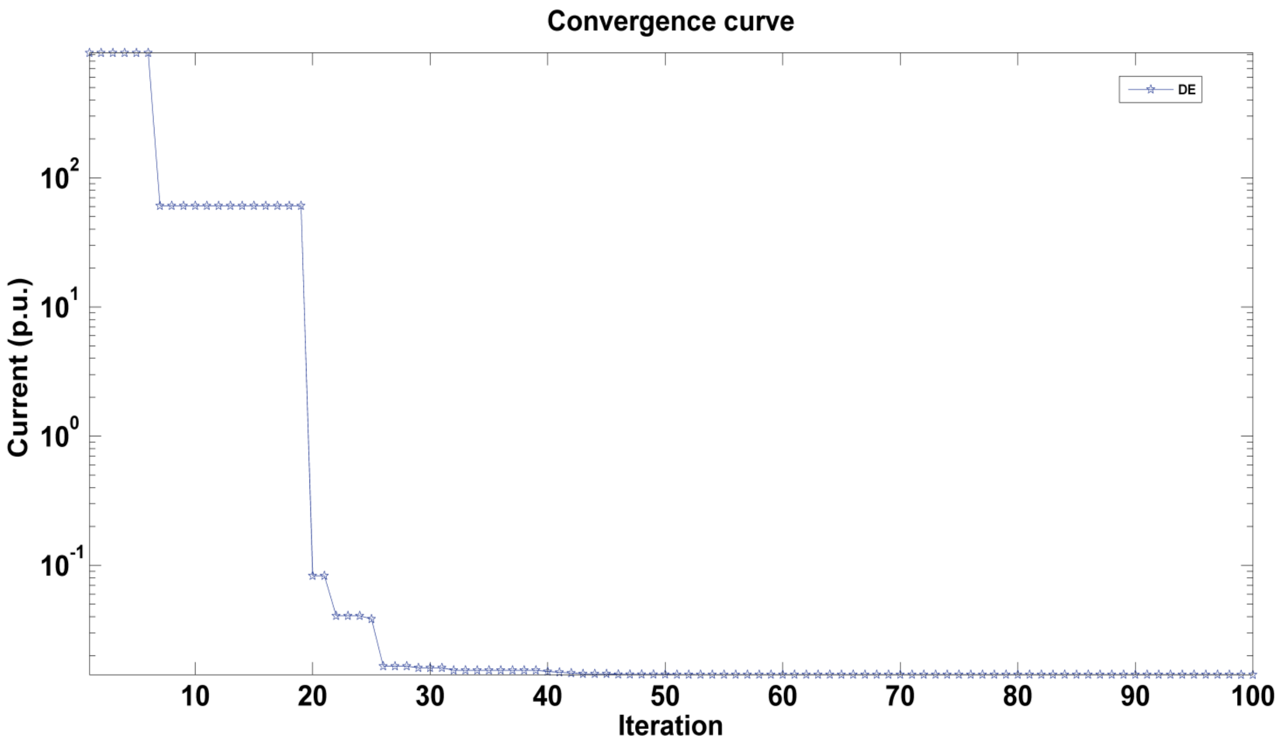


**Fig. 4** Convergence curve of optimization algorithm DE with bus at 27

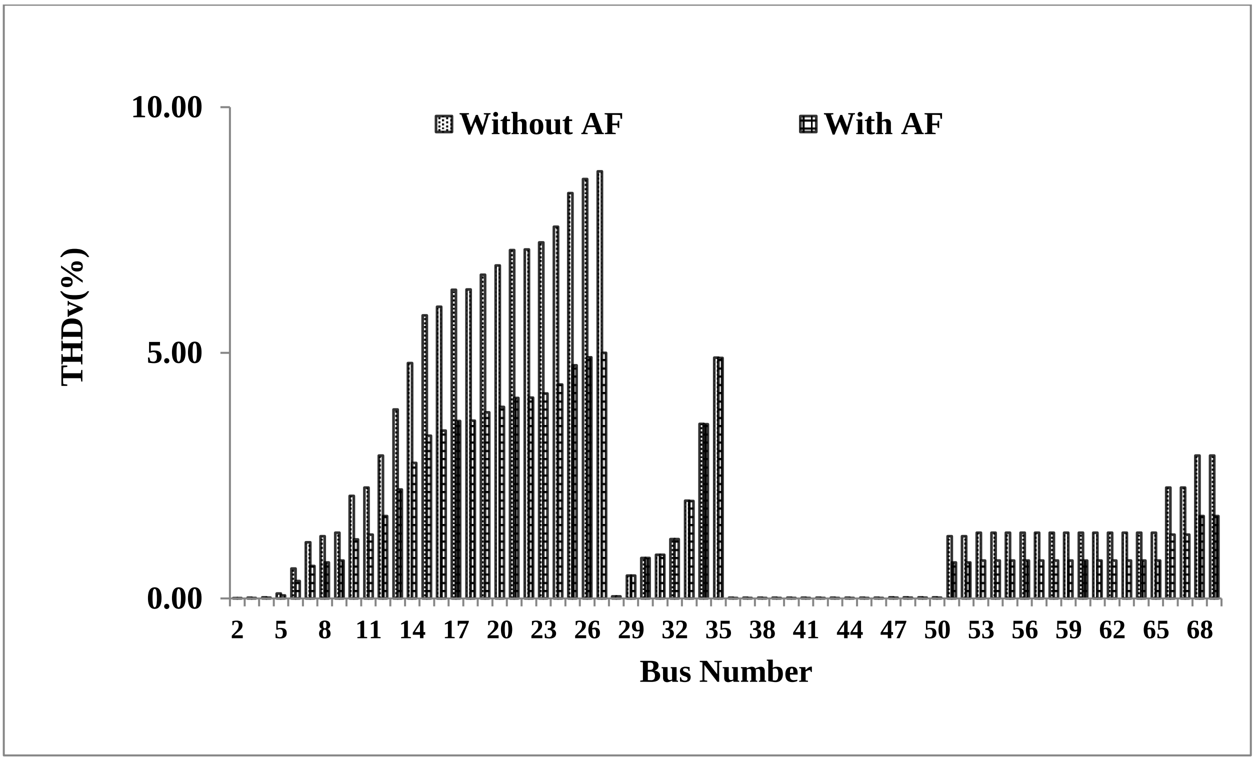


**Fig. 5** The THDv at all buses with AF and without AF

## IV. CONCLUSION

The proper placement of AF in RDS using DE is employed in this paper. The DE is coupled with harmonic load flow and results are simulated for IEEE-69 bus test system successfully. It is clearly observed that even only two NLs are connected in RDS; harmonics are propagated into the RDS. Moreover, thirteen buses have THDv more than 5%. The highest THDv is calculated at bus 27 (8.69%). Total thirteen buses have THDv above the limit. This shows the impact of harmonics into the RDS results in poor PQ. Here, the placement of AF is important; when AF is placed at bus 35 it cannot be reduced the harmonics to standard limit. While by placing the AF at bus 27 all the buses have THDv less than 5%. Only one AF is sufficient to reduce the THDv within limit at all buses of entire RDS. DE has found the AF current (0.0142 p.u.), which is fulfilled the requirement. The DE is converged successfully for AF placement at bus 27 with AF current of 0.0142 p.u.. The DE is not converged at bus 35. It shows the importance of placement of AF.

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