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Optimal placement and sizing of DSTATCOM using Harmony Search algorithm

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Abstract

This paper investigates a new approach to find the optimal location and sizing of Distribution STATic COMpensator (DSTATCOM) with an objective function of minimizing the total network power losses. Harmony search algorithm is used to find the optimal location and sizing of DSTATCOM. The proposed work is tested on standard IEEE 33-bus radial distribution systems. The obtained result shows that optimal placement and sizing of DSTATCOM in the radial distribution network effectively reduces the total power losses of the system.

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Keywords: Distribution STATic COMpensator (DSTATCOM), Harmony Search Algorithm, Radial Distribution Network.

1. Introduction

So many researchers approximated that in the distribution side 13% of total generated power is wasted as a loss [1]. From the consumer point of view, the power loss reduction is one of the important issue to improve the overall efficiency of the power delivery. So we need to use highly advanced equipment's for power loss reduction of the distribution network. Such equipment's are capacitor banks, shunt and series reactors, Automatic Voltage Regulator (AVR) or recently developed Distribution network Flexible AC Transmission (DFACTS) such as Distribution STATic COMpensator (DSTATCOM), Unified Power Flow Conditioner (UPQC), and Static Synchronous Series Compensator (SSSC) [2-4]. Compare with

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other reactive power compensation devices, DSTATCOM has many features, such as low power losses, less harmonic production, high regulatory capability, low cost and compact size [5].

DSTATCOM is a shunt connected Voltage Source Converter (VSC) which has been applied in distribution networks to compensate the bus voltage so as to provide power factor and reactive power control. DSTATCOM can inject correct amount of leading or lagging compensating current when it is associated with a specific load so that the total demand meets the specification for utility connection [6]. DSTATCOM is predicted to play significant role in the radial distribution systems due to the increasing power system load. Optimum allocation of DSTATCOM maximize the load ability, power loss minimization, stability enhancement, reactive power compensation and power quality enhancement [7].
Based on the literature review, to determine the optimal location and sizing of DSTATCOM has a considerable impact in radial distribution system. Inappropriate placement in some situations can reduce the benefits and even endanger the entire system operation [8, 9]. Only a few research works were done in the area of DSTATCOM allocation. In ref [10], a differential evolution algorithm is presented for optimal DSTATCOM allocation in radial distribution system with reconfiguration consideration. In [11], an immune algorithm approach for determining the optimal location and size of DSTATCOM with an objective function of minimize the cost of total active power loss is investigated. Then in [12] particle swarm optimization algorithm is used for determining the optimal location and sizing of DSTATCOM and DG with an objective function of power loss minimization and voltage profile improvement.
In this paper, harmony search algorithm has been proposed to find the optimal location and sizing of the DSTATCOM in the radial distribution network to reduce the total power losses. The proposed method is tested on IEEE 33- bus radial distribution system. The obtained results are compared with the other existing methods which founds to be better than that of other existing methods.

2. Problem formulation

2.1. Power flow analysis

In this paper, a direct approach for distribution system load flow solution has been used for better solution [13].The single line diagram of simple distribution system is shown in Fig 1.

From Fig. 1, the equivalent injected current at node t is given as

$$I_t = \left(\frac{P_t + jQ_t}{V_t} \right)^* \tag{1}$$

From Fig. 1, Kirchhoff's current law used to calculate the branch current in the line section between buses t and t+1, which is given as

$$J_{t,t+1} = I_{t+1} + I_{t+2} \tag{2}$$

By using the Bus Injected to Branch Current matrix (BIBC)

$$[J] = [BIBC][I] \tag{3}$$

From Fig 1, Kirchhoff's voltage law used to calculate the voltage at buses t+1, which is given as

$$V_{t+1} = V_t - J_{t,t+1}(R_{t,t+1} + jX_{t,t+1}) \tag{4}$$

The real and reactive power loss in the line section between buses t and t+1 can be calculated as

$$P_{Loss(tt+1)} = \left(\frac{P_{t,t+1}^2 + Q_{t,t+1}^2}{\left|V_{t,t+1}\right|^2} \right) * R_{t,t+1} \quad (5)$$

The total power loss (P_{TLoss}) of the distribution systems is found by the addition of losses in all line sections, which is given by

$$P_{TLoss} = \sum_{t=1}^{nb} P_{Loss(tt+1)} \quad (6)$$

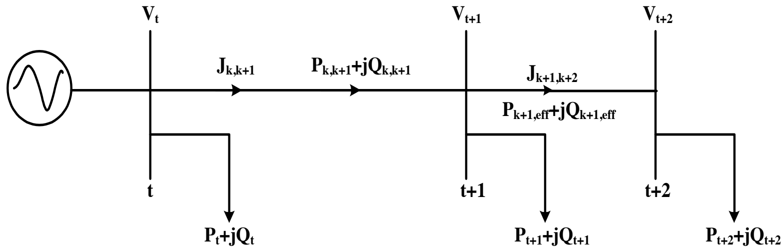

Fig.1. Simple distribution system.

2.2. Objective Function

The objective of DSTATCOM placement in the radial distribution system is to minimize the total power losses while satisfying the equality and inequality constraints. The mathematical formulation of the objective function (F) is given by

$$\text{Minimize}(F) = Min(P_{TLoss}) \quad (7)$$

Problem Constraints:
The equality and inequality constraints considered in the problem are:
Voltage deviation limit

$$V_t^{min} \le |V_t| \le V_t^{max}$$

Power Balance constraints

$$P_{TLoss} + \sum P_D = \sum P_{DSTATCOM}$$

Reactive power compensation

$$Q_{ct}^{min} \le Q_{ct} \le Q_{ct}^{max} \ ,t = 1,......, nb$$

3. Harmony Search Algorithm

The steps involved in the Harmony search algorithm is
Step 1: Initialize the input data

$NVAR(1)$	: The number of variables, i.e. the number of DSTATCOM Placement
$NG(2)$	: The number of inequality constraints
$NH(1)$	: The number of equality constraints
$Max_{Itr}(1000)$	: The maximum number of iteration for this problem.
$HMS(6)$	: Harmony memory size.
$HMCR(0.9)$	: Harmony consideration rate 0< HMCR <1
$PAR_{\min}(0.4)$	: Minimum pitch adjusting rate
$PAR_{\max}(0.9)$	: Maximum pitch adjusting rate
$BW_{\min}(0.0001)$	: Minimum bandwidth
$BW_{\max}(1.0)$	: Maximum bandwidth

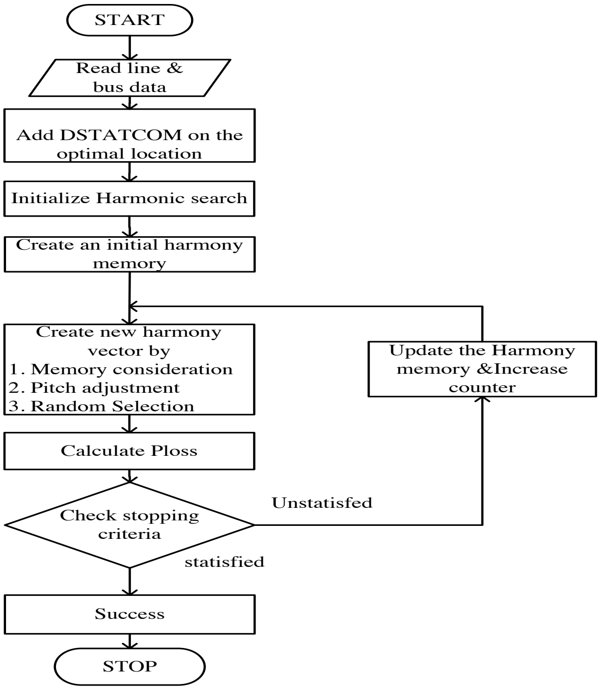

Fig.2. Flow chart of harmony search algorithm.

Step 2: Initialize Harmony Memory as

$$x_j^i = x_j^L + rand(0,1) * (x_j^U - x_j^L) \tag{8}$$

$$HM = \begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_{N-1}^1 & x_N^1 \\ x_1^2 & x_1^2 & \cdots & x_{N-1}^2 & x_N^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{HMS-1} & x_2^{HMS-1} & \cdots & x_{N-1}^{HMS-1} & x_N^{HMS-1} \\ x_1^{HMS} & x_2^{HMS} & \cdots & x_{N-1}^{HMS} & x_N^{HMS} \end{bmatrix}$$

Step 3: Update the member for all result vector in Harmony search
Generation of the random number according to minimum and maximum limit.
Step 4: Test for convergence.

Compare previous P_{TLoss} value with the new P_{TLoss} value. If the P_{TLoss} value is small then the preset value (0.00001), then the process will end and the last calculated P_{TLoss} value will be accepted, otherwise the process will continue until the P_{TLoss} value difference smaller than the present value. The figure 2 shows the flow chart of the harmony search algorithm. Finally the algorithm will give the optimal size of the DSTATCOM.
Hence this steps have to be follow in order to minimize the objective function.

4. Simulation result and discussion

IEEE 33-bus test system

To show the effectiveness and performance of proposed method, it has been tested on standard IEEE 33-bus systems. The line and bus data are taken from [14]. The line voltage, real and reactive power loads of the radial distribution networks are 12.66 kV, 3.72 MW and 2.3 MVAr, respectively. The single line diagram of IEEE 33-bus radial distribution system shown in fig 3. The OF parameters used for test system is shown in table 1. The proposed method has been programmed and implemented using MATLAB environment to run distribution system load flow, calculate real and reactive power losses and to identify the optimal location and size of DSTATCOM. In this system, the 30th bus is selected for optimal DSTATCOM installation. The voltage profile of the 33-bus with and without DSTATCOM is shown in figure 4. From fig 4, it can be noted that implementation of DSTATCOM in the radial distribution system has improved the voltage profile effectively.

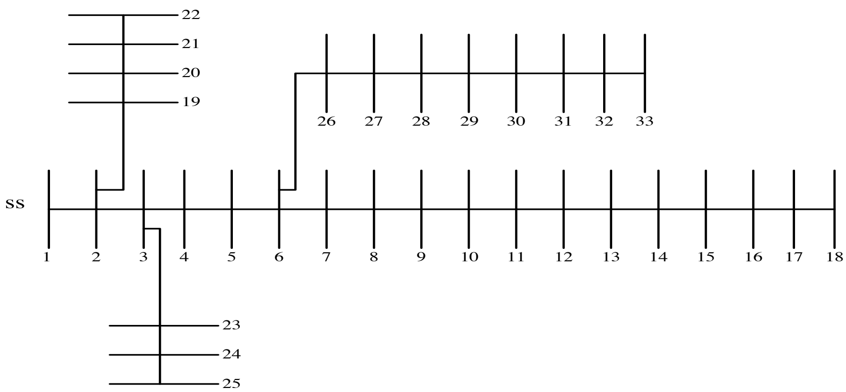

Fig.3. Single line diagram of IEEE 33-bus system.

Table 1
Objective Function parameters settings for optimization.

$DSTATCOM_{cost}$ (\$/kVAr)	$n_{DSTATCOM}$ (year)	B	K_p (\$/kWh)	K_c	T
50	30	0.1	0.06	1	8760

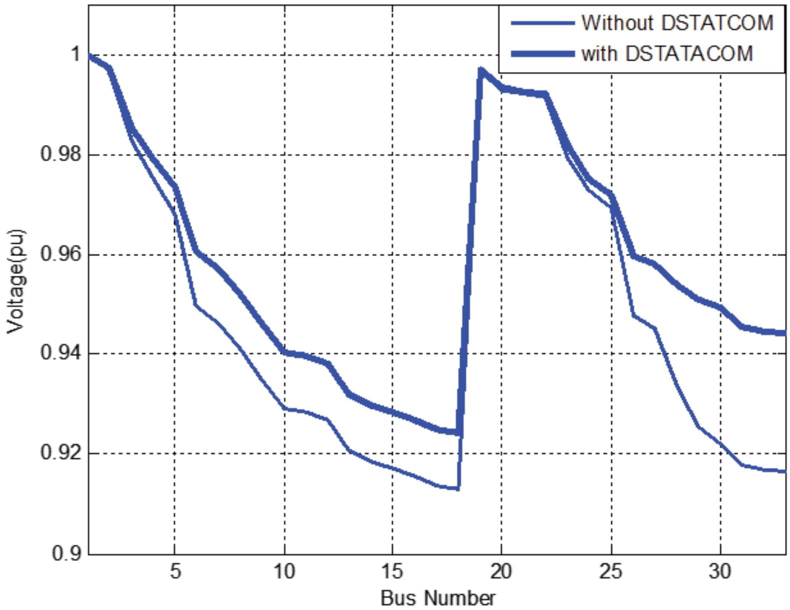

Fig 4 Voltage profile improvement for 33 bus system

Table 2
Performance analysis of the proposed method after installation of DSTATCOM on 33-bus system.

Items	Base case	Immune Algorithm[11]	Proposed Method
Optimal size (kVAr)&Location	-------	962.49(12)	**1150(30)**
P_{loss} (kW)	202.67	171.79	**143.97**
Q_{loss} (kVAr)	135.24	115.26	**96.47**
$V_{\min}$ (p.u)	0.9131	0.9258	**0.9236**
Total annual cost saving ($)	-------	11,130	**24,264**

The annual cost of DSTATCOM can be calculated by using the equation (9):

$$DSTATCOM_{cost,year} = DSTATCOM_{cost} \frac{(1+B)^{n_{DSTATCOM}} \times B}{(1+B)^{n_{DSTATCOM}} - 1} \tag{9}$$

Where $DSTATCOM_{cost,year}$ is the annual cost of DSTATCOM, and $DSTATCOM_{cost}$ is the cost of investment in the year of allocation ($/kVAr). B is the asset rate of return and $n_{DSTATCOM}$ is the longevity of DSTATCOM.

Total Cost Saving (TCS) of DSTATCOM is the difference between total energy loss cost before installation and total energy loss cost and annual DSTATCOM after installation and it is given by equation (10).

$$TCS = K_p(T \times P_{TLoss}) - K_p(T \times P_{TLoss}^{withDSTATCOM}) - (K_c \times DSTATCOM_{\cos t,year}) \quad (10)$$

Where K_p , K_c , T indicate the cost of energy losses, time duration proportion and hours per year respectively. P_{TLoss} is the total power loss before installation of DSTATCOM and $P_{TLoss}^{withDSTATCOM}$ is the total power loss after installation of DSTATCOM.

Table 2 shows the comparison of real and reactive power losses, locations, optimal size (kVAr) and total annual cost saving for existing and proposed methods. In the proposed method, the real and reactive power losses have been reduced to 143.97kW (i.e. percentage of reduction is 28.97%) and 96.47kVAr (i.e. percentage of reduction is 28.67%) after installing the DSTATCOM. The proposed method total power losses reduction is high compared to existing Immune Algorithm method. And the total annual cost saving is $ 24264, which is the highest total annual cost saving compared to immune algorithm. This shows that the proposed harmony search algorithm based optimization is more effective than the Immune Algorithm based optimization.

5. Conclusion

This paper presents a new approach to find optimal location and sizing for DSTATCOM in the radial distribution network. The proposed method has been tested on standard IEEE 33-bus system. From simulated results, it can be noted that implementation of DSTATCOM in the radial distribution system has reduced the total power losses effectively which is better than existing IA method. It can be concluded that the proposed harmony search algorithm based technique is very accurate in finding the optimum solutions and it can be implemented for n number of buses.

References

1. Attia A. EI-Fergany.: Optimal capacitor allocations using evolutionary algorithms. IET Gener.Transm. Distrib. Feb (2013) 593-601.
2. Acha E, Agelidis VG, Anaya-Lara O, Miller TJE. Power electronic control in electrical systems, Newnes; 2002.
3. Ghosh A, Ledwich G. Compensation of distribution system voltage using DVR.IEEE Trans Power Del 2002; 17 (4):1030–6.
4. Zhang XP. Advanced modeling of the multi-control functional static synchronous series compensator (SSSC) in Newton power flow. IEEE Trans Power Syst 2003; 18 (4):1410–6.
5. Z. Yang, C Shen, M. L. Crow and L. Zhang, “An Improved STATCOM Model for Power Flow Analysis,” Power Engineering Society Summer Meeting, Vol. 2, Seattle, 16-20 July 2000, pp. 1121-1126.
6. Sensarma PS, Padiyar KR, Ramanarayanan V. Analysis and performance evaluation of a distribution STATCOM for compensating voltage fluctuations. IEEE Trans Power Del 2001; 16 (2):259–64.
7. Wasiak I, Mienski R, Pawelek R, Gburczyk P. Application of DSTATCOM compensators for mitigation of power quality disturbances in low voltage grid with distributed generation. In: 9th International conference on electrical power quality and utilizations; 2007.
8. Mohamed Imran A, Kowsalya M. Optimal size and siting of multiple distributed generators in distribution system using bacterial foraging optimization Swarm and Evolutionary Computation 15, 2014;58–65.
9. Devabalaji KR, Ravi K, Kothari DP. Optimal location and sizing of capacitor placement in radial distribution system using bacterial foraging optimization algorithm. Int J Electric Energy Syst 2015; 71:383–90.
10. S. Jazebi, S.H. Hosseinian, B. Vahidi. DSTATCOM allocation in distribution networks considering reconfiguration using differential evolution algorithm, Energy Conversion and Management 52 (2011) 2777–2783
11. Seyed Abbas Taher, Seyed Ahmadreza Afsari. Optimal location and sizing of DSTATCOM in distribution systems by immune algorithm, Electrical Power and Energy Systems 60 (2014) 34–44.
12. S. Devi, M. Geethanjali. Optimal location and sizing determination of Distributed Generation and DSTATCOM using Particle Swarm Optimization algorithm, Electrical Power and Energy Systems 62 (2014) 562–570
13. Teng Jen-Hao. A direct approach for distribution system load flow solutions. IEEE Trans Power Deliv 2003; 18 (3):882–7.
14. N.C.Sahoo, K.Prasad, A fuzzy genetic approach for network reconfiguration to enhance voltage stability in radial distribution systems, Energy Convers. Manage. 47(2006)3288–3306.