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FOOTBALL GAME OPTIMIZATION BASED CAPACITOR PLACEMENT FOR LOSS MINIMIZATION

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ABSTRACT

Present day distribution networks operating at lower voltages waste major part of generated power as loss. Capacitor banks (CBs) are usually placed to supply VARs and reduce the real power loss. It may not be possible to place CBs at all nodes but can be placed only at selected number of buses for economic reasons. Recently football game based optimization (FGBO) was suggested to solve real world optimization problems. This paper builds the CB placement problem as an optimization problem and employs FGBO for solving the problem. It applies the developed algorithm on two test systems and presents the results.

Keywords: distribution network, loss minimization, capacitor placement, football game based optimization.

1. INTRODUCTION

Distribution networks cause a major part of active power losses, while distributing power to consumers at lower operating voltages with high currents to meet the consumer demand, than that of high voltage transmission system. It has been studied that nearly 15% of produced real power is wasted as loss in distribution networks. Besides, the progressive drop over distribution feeders leading to very low tail end voltages, causing poor voltage profile of the network. The loss can be reduced and poor voltage profile can be improved through traditionally providing appropriate VAR support at critical nodes by installing capacitor banks (CBs).

Many techniques and methodologies were developed by researchers during recent decades. A simple loss reduction method involving application curves for determining sizes of capacitor banks and the nodes for placement along the feeder for a network with uniformly distributed and well balanced loads was presented by Neagle and Samson [1]. A non-linear programming based iterative strategy for placement and rating of capacitor banks was presented by Grainger and Lee [2], wherein the size of capacitors was treated as continuous variables. A capacitor placement strategy involving GA for improving the power quality of distribution networks was suggested by Mohammead *et al.* This strategy also determines the size of capacitors [3]. A GA based optimal allocation of CBs in distribution networks was outlined by Masoum et al. with a view of lowering the power and energy losses, and enhancing the power quality, while accounting the current and voltage harmonics [4]. Analytical strategies for finding best locations and rating of CBs for enhancing voltage stability of distribution networks was suggested by Mohan and Aravindhababu. The developed strategies were exhibited to enhance the voltage profile and lower the network losses besides addressing voltage stability [5, 6]. A fuzzy based strategy for optimally determining the nodes and rating of CBs for avoiding voltage instability was outlined by Balamurugan and Aravindhababu [7]. A PSO based technique for best rating of CBs for placement in unbalanced distribution networks by Abdelsalam and El-Hawary. The method also accounts harmonics for placement [8]. A classical kind of method for finding optimal nodes for CB placement and rating of CBs for enhancing voltage stability of distribution networks was suggested by Arun and Aravindhababu [9]. Shuaib and Christober Asir Rajan employed Queen bee guided GA for solving the CB placement problem in a distribution system, wherein sensitivity analysis was performed for selection of candidate locations for placement [10]. Deepti Sharma and Amita Mahor employed loss sensitivity factors and refined GA for identifying candidate nodes and rating of CBs. The refined GA was tailored to lower the cost associated with energy loss and CB cost [11]. Several optimization techniques such as classical, artificial intelligence and meta-heuristic approaches for placement of CBs were reviewed and compared with simulation study by Aman *et al.* [12]. GA was employed for obtaining the best nodes location and ratings of CBs, while considering one year load data, in distribution networks by Mohamed Ahmed Mehanna1, Mokhtar Hussien Abdullah [13]. The method was tailored to account CB price, maintenance rate, electrical cost and loss rate.

Recently a football game based optimization (FGBO), which belongs to the family meta-heuristic optimization algorithms, was proposed for solving optimization problems and exhibited to be better than other meta-heuristic algorithms like genetic algorithm, honey bee algorithm, and so on [14]. In this approach, each player indicates a probable solution point and randomly moves to a good position to receive the ball with an objective of scoring a goal under the guidance of a coach. In this article, FBGO is applied in solving the CB placement problem.

2. PROBLEM FORMULATION

The CB placement problem is tailored as an optimization problem:

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Minimize $\Phi = \sum_{j=1}^{nfeeder} I_j^2 r_j$ (1)

Subject to

$$P_{Gk} - P_{Dk} - P_k(V,\delta) = 0 \quad (2)$$

$$Q_{Gk} - Q_{Dk} - Q_k(V,\delta) = 0 \quad (3)$$

$$V_k^{\min} \le V_k \le V_k^{\max} \quad (4)$$

$$Q_{C-k}^{\min} \le Q_{C-k} \le Q_{C-k}^{\max} \quad (5)$$

Where

V_k is voltage magnitude at node- k .

$V_k^{\min}$ and $V_k^{\max}$ is the lower and upper k -th node voltage.

Q_{C-k} is the VAR support by CBs at node- k .

$Q_{C-k}^{\min}$ and $Q_{C-k}^{\max}$ is the minimum and maximum permissible VAR support respectively at node- k .

3. PROPOSED METHOD

The goal of the PM is to determine optimal node locations for CB placement and their ratings with a goal of minimizing the network loss. The variables are node locations and the number of CBs. The basic available capacity and the number of CB at a selected node will yield the total VAR support to be provided at that node. Each player is defined to denote the problem variables as

$$P_i = [L_1,\ L_2, \cdots, L_{nnc}, N_1,\ N_2, \cdots, N_{nnc}] \quad (6)$$

The performance of each player is evaluated by a performance function (PF), which is formed from objective function.

$$PF = \frac{1}{1 + \sum_{j=1}^{nfeeder} I_j^2 r_j} \quad (7)$$

The random walks of players under the supervision of game coach in obtaining a goal are done by two phases as outlined below:

3.1 Random Walk

Each player walks randomly without receiving any command from the game coach by

$$P_i^t = P_i^{t-1} + \delta_i\ \sigma + \gamma\left(P_{Ball}^t - P_i^{t-1}\right) \quad (8)$$

where

P_i^t : i-th player's position.

δ and γ : random numbers.

σ_i is the step size reduced during solution process by $\sigma_i = \sigma_o \theta$.

θ is a fixed number.

P_{Ball}^t : location of the player with ball at instant t.

3.2 Coaching

The player increase the tension on opponent placer by forward movement based on the command from game coach depending on the hyper distance (HD) among players.

$$HD_i = \left\| P_i^{t-1} - P_{best}^{t-1} \right\| \quad (9)$$

The players with higher HD values than a threshold $\Re$ are moved towards the nearby best locations, $P_{nearest-best}^{t-1}$:

$$P_i^t = P_{nearest-best}^{t-1} + \sigma_i\ \delta \quad (11)$$

$\Re$ is progressively lowered towards its selected lowest value ($\Re_{\min}$) by Eq. (11).

$$\Re^t = \Re_{\min} + \eta(\Re^{t-1} - \Re_{\min}) \quad (12)$$

where η represents a constant.

In substitution plan, the team coach discards inefficient players by good ones so as to enhance the possibility of obtaining a goal. Each good player, whose CFV is greater than cost constraint value ($\Im$), are swapped by a nearby efficient player in accordance with coach memory (CM) by Eq. (10). $\Im$ is lowered in steps as the iteration progresses by Eq. (24).

$$\Im^t = \Im_{\min} + \lambda(\Im^{t-1} - \Im_{\min}) \quad (13)$$

where λ is an succession constant.

If the new player moves away from the football pitch, he is brought back into the football pitch by Eq. (10).

3.3 Solution Process

A team of players is initially produced by random values, their PFs are evaluated by Eq. (7) and they are ranked based on the PFs. The HD between each player and the most efficient player is computed. The phases of random walk and coaching are performed by Eq. (8) and Eq. (10) respectively. The process of evaluating PFs, and HDs and performing random walk and coaching indicates iteration, and this process is repeated till convergence. The efficient player possessing largest PF after convergence is considered as the optimal solution.

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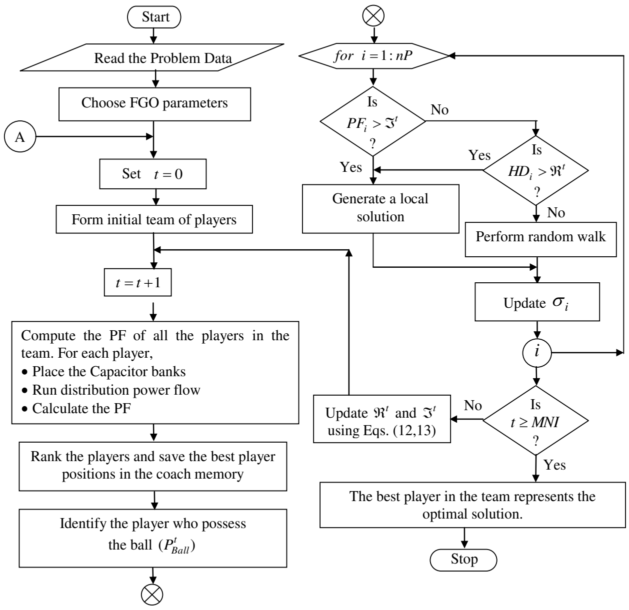

Figure-1. Proposed CB Placement Algorithm.

4. RESULTS AND DISCUSSIONS

The proposed strategy was applied on 33 and 69-node distribution networks [15, 16]. The distribution power flow presented in [17] was employed. The basic size of CBs was chosen as 150 kVAR. The number of node locations for placement are taken as 3 and 4 for 33 and 69 node systems respectively.

33 node test system: The node locations and number of CBs, provided by the developed method are furnished in Table-1. The system requires 4, 6 and 3 number of CBs, each rated for 150 kVAR, for placement at node locations of 14, 30 and 32 respectively. The network loss and lowest voltage noticed in the network are given in Table-2 before and after CB placement. This table indicates that the CB placement lowers the loss from 210.97 kW to 146.19 kW, besides improving the lowest voltage of 0.904 per unit to 0.942 per unit.

Table-1. Optimal solution for 33 node system.

Node No.	**14**	**30**	**32**
No of CBs	4	6	3
kVAR rating	600	900	450

Table-2. Performance for 33 node system.

Before		**After**	
V^{low}	Loss (kW)	V^{low}	Loss (kW)
0.904	210.97	0.942	146.19

69 node test system: The node locations and number of CBs provided by the developed method are furnished in Table-3. The system requires 7, 1, 2 and 1 number of CBs, each rated for 150 kVAR, for placement at node locations of 61, 62, 63 and 64 respectively. The network loss and lowest voltage noticed in the network are given in Table-4 before and after CB placement. This table indicates that the CB placement lowers the loss from 192.88 kW to 134.22 kW, besides improving the lowest voltage of 0.903 per unit to 0.934 per unit.

Table-3. Optimal solution for 69 node system.

Node No.	**61**	**62**	**63**	**64**
No of CBs	7	1	2	1
kVAR rating	1050	150	300	150

Table-4. Performance for 69 node system.

Before		**After**	
V^{low}	Loss (kW)	V^{low}	Loss (kW)
0.903	192.88	0.934	134.22

5. CONCLUSIONS

Football game based Algorithm is nature inspired technique for solving optimization problems. This technique models the behavior of football players for solving the problems. This technique was applied to solve optimal CB placement problem by treating the node locations and number of CB to be placed as firefly. The results on 33 and 69 node system clearly exhibit that the proposed method is very effective in lowering the network loss and improving the voltage profile.

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