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Distribution Network Reconfiguration and D-STATCOM Allocation using Variational Technique

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Abstract— This paper explores feeder reconfiguration alongside distributed static compensator (D-STATCOM) in distribution systems. An efficient method is present to optimize the radial distribution structure by means of reconfiguration along with allocation of distributed static compensator. Network Reconfiguration of distribution system is a momentous way of revising the power flow through the various alternative lines with an objective of minimizing real power loss distribution system. A precise and load flow algorithm is useful and the objective function is formulated to solve the fitness function, which includes D-STATCOM for reactive power compensation to minimize the power losses. Particle swarm optimization is exploited to restructure and recognize the best strap switches for minimization of real power loss in a distribution network. Fuzzy analysis is projected to find the optimal location of D-STATCOM. Variational Technique is used to identify the optimal size of D-STATCOM. This has been tested on IEEE 33-bus system to prove the adequacy of the technique using MATLAB software.

Keywords* — *COVID Fuzzy Approach; Particle Swarm Optimization; **D**-STATCOM; Feeder Reconfiguration.

1. Introduction

Feeder reconfiguration is that the process of adjusting the distribution topology by altering the status of the switches. There are two types of switches and their status are normally open and normally close. In reconfiguration process, the status of these switches will be amended optimally based on objective function.

Walmir Freitas [1] proposed, DSTATCOM voltage controller can improve the stability performance of induction generators significantly. Bhim Singh [2], described a modified version of instantaneous reactive power theory is used for control of DSTATCOM. Damodar Reddy [3], a fuzzy multi-objective algorithm is used to solve optimal capacitor placement and reconfiguration.

Hooshmand [4] introduced bacterial foraging using PSO algorithm for optimal location of fixed and switching capacitors to reduce the costs of power losses and to improve the voltage profile. A two-stage method of finding the optimal locations and sizes of shunt capacitors for loss reduction is used in Damodar Reddy [5]. Gawande [6], the first stage the reactive power absorption is reduced by considerable amount. In the next stage when the distribution static compensator (DSTATCOM) of calculated capacity is connected at point of common coupling and to scale back the burden & satisfactory improvement in reactive power characteristics of generator. Arya [7], proposed implementation of three phase distribution static compensator (DSTATCOM) using single phase p-q theory based control algorithm for DSTATCOM in power factor correction under nonlinear distribution system. Suhail [8] proposes a methodology to identify the optimum location of DSTATCOM for minimizing the losses and voltage profile improvement in radial distribution system. El-Fergany [9], an efficient heuristic based approach to assign static shunt capacitors using ABC algorithm to enhance overall system static voltage stability index and achieve maximum savings.

Taher [10], to find the optimal location and sizing of DSTATCOM for power loss reduction and improvement of current and voltage profile in distribution systems. Sanam [11], A new mathematical modelling of DSTATCOM is derived and is integrated into the forward-backward sweep load flow algorithm to compensate the reactive power. Gupta [12], proposed optimal location and size of D-STATCOM is determined for radial distribution networks for loss reduction, improvement of voltage profile and overall energy savings. Sudhakara Reddy to be published [13] proposed dragonfly algorithm to resolve the ultimate network reconfiguration and reduce the system losses. Sudhakara Reddy submitted for publication [14] proposed PSO algorithm to determine the optimal network reconfiguration to reduce the real power losses and improve voltage profile. Karami[15], proposed multi-objective function which includes system loadability, and total costs include investment costs of distributed generations and DSTATCOMs and network loss.

2. Problem Formulation

Calculation of load current - A sample system as shown in Fig. 1 below, the complex power injected into the bus is given by $S_n = P_n + jQ_n = V_n I$

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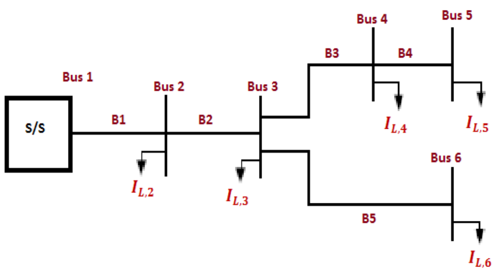

Fig 1: Sample system

The load current at any bus n is given by $I_{L,n} = \left(\frac{P_n+jQ_n}{V_n}\right)^* = \frac{P_n-j}{V_r}$ (1)

Where $n = 1, 2, 3, \ldots\ldots\ldots N$
Where N = total number of buses
ILn= load currents@ bus n
Pn = real power demand@ bus n
Qn = reactive power demand@ bus n
Vn = bus voltage@ bus n

Formation of BIBC matrix - By using KCL, equations for branch currents represented in terms of load currents are given by

$I_{B1}= I_{L2}+I_{L3}+ I_{L4}+ I_{L5}+ I_{L6}$ (2)
$I_{B2}= I_{L3}+ I_{L4}+ I_{L5}+ I_{L6}$ (3)
$I_{B3}= I_{L4}+ I_{L5}$ (4)
$I_{B4}= I_{L5}$ (5)
$I_{B5}= I_{L6}$ (6)

Thus the relationship between load currents and branch currents can be expressed in matrix form is given by [IB]=[BIBC] [IL] (7)

Forward sweep - The total real power loss during a balanced radial distribution system consisting of b branches are often written as $P_{LT}= \sum_{i=1}^{b} I_i^2$ (8)

Radiality constraint - The switching loops corresponding to reconfiguration as shown in Table 1. Basic configuration = [S33, S34, S35, S36, S37].

Table 1: Switching Loops

Test System	LSW
33 - Bus Test System	9 10 11 35; 27 28 37 0; 7 6 33 0; 31 32 36 0; 13 14 34 0

LSW is used for the optimal switching to maintain the radial structure in the distribution systems and maintain minimum loss in each loop [14].

Objective Function - Fitness function = min { P_{l_t} } (9)

3. Particle Swarm Optimization

Algorithm - Optimal Reconfiguration by PSO method

Step 1: Initialize the randomly generated particles, number of tie-switches by maintaining the system is in radial structure.
Step 2: Similarly the amount of initial velocity of every particle is randomly generated and number of tie-switches.
Step 3: Analyze the all possible configurations, all particles are randomly generated and number of tie-switches.
Step 4: pbest values for all the particles are obtained on the basis of fitness values and therefore the best value among the all pbest values are (gbest).
Step 5: All new velocities of the particles are calculated using the equation (10)

$$V_{ij}^{t+1} = \omega V_{ij}^{t} + c_1 r_{1j}^{t}\left[P_{best,i}^{t} - x_{ij}^{t}\right] + c_2 r_{2j}^{t}\left[G_{best,i}^{t} - x_{ij}^{t}\right] \quad (10)$$

Step 6: The position of each particle is modified by equation (11)

$$X_i^{k+1} = X_i^k + V_i^k \quad (11)$$

Step 7: Update new fitness are according to the new positions of all particles. If the new fitness value for any particle is best than previous pbest then pbest value for that particle is about to present fitness value using the equation (14).

$$P_{best,t}^{t+1} = \begin{cases} P_{best,t}^{t} iff(x_i^{t+1}) > P_{bes}^{t} \\ x_i^{t+1} iff(x_i^{t+1}) \leq P_{best}^{t} \end{cases} \quad (12)$$

Step 8: The gbest value defined from the latest pbest values by using equation (12)

$$G_{best} = min\{P_{best,}^{t} \quad (13)$$

Step 9: The iteration count is increased and if the iteration count isn't reached maximum then attend step (3).
Step 10: Finally, gbest particle gives the reduced real power loss for the reconfigured network and like final reconfiguration gives the simplest or optimal network reconfiguration of a radial distribution system.

4. Optimal Location of D-Statcom By PLRI

4.1 Power Loss Reduction Index (PLRI)

The candidate bus for the location of D-STATCOM is found during this section. The PLRI approach is an efficient process to pick the simplest location of D-STATCOM, which is sensitive with significant effect on

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the TPL reduction.

Power loss reduction index (PLRI) is given by

$$\mu_L^i = \frac{[P_L^{Max} - f_L(\lambda}{(P_L^{Max} - P_L^{Mi}} \quad (14)$$

The bus having the very best PLRI value is that the most complimentary bus and thus selected as candidate bus for D-STATCOM placement. The steps for calculating PLRI are:

Step 1: Read the radial distribution and bus data after optimal network identification.
Step 2: Calculate voltages for all the buses and power losses for all the branches.
Step 3: Calculate power loss reduction index (PLRI) using equation (14).
Step 4: Select the bus with highest value of PLRI as candidate bus as shown in figure 3.
Step 5: Stop.

For 33-bus test system, 30th bus is getting the very best value of PLRI and 30th bus is getting the very best value of DPSI 0.8379 as are often seen from fis system. So it is a candidate bus for D-STATCOM placement.

5. Variational Technique

5.1 Optimal Size of D-STATCOM

The D-STATCOM maintains the reactive power to minimize the power loss of RDS. In this proposed work, $Q_{DS}$is varied between the 10 kVAr to 2000 kVAr to determine the maximum possible reduction in power loss. The proposed load flow algorithm has to two stages of evaluation, first stage is optimal network reconfiguration and second stage is placement and size of D-STATCOM for the optimally reconfigured network. The variational technique is used to find the capacity of DSTATCOM. The following steps are used for finding the optimum size of D-STATCOM for the optimal reconfigured network.

Calculation of the optimum size of D-STATCOM

Step 1: Identify the line data and bus data for the reconfigured network and find the hopeful bus for D-STATCOM placement by any sensitivity (D-PSI).
Step 2: Keep D-STATCOM at candidate bus with varying size in steps of 1 KVAR up to max load. Find the Power losses after placement of D-STATCOM for the reconfigured network.
Step 3: Select the Optimal size of D-STATCOM which gives minimum losses for the optimal reconfigured network.
Step 4: Stop.

From, the variational technique algorithm, the minimum losses represents after D-STATCOM is implemented for the optimal reconfigured network.

6. Matlab Results

6.1 Basic Configuration of IEEE 33-Bus System

The location of D-STATCOM is decided based on the sensitivity as shown in Fig.3.The final optimal reconfiguration and results of the IEEE 33-bus test system using MATLAB is shown in figure 2.

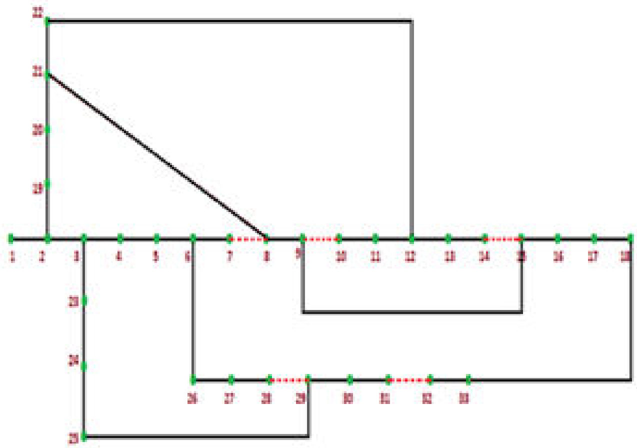

Fig. 2: Optimal Network Reconfiguration

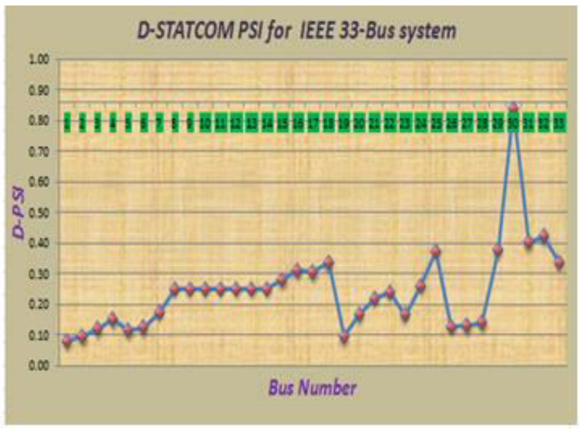

Fig. 3: Priority for Location of D-STATCOM

7. Conclusion

In the past work [9] and [10], the reconfiguration predicament is resolved optimally to lowers the real losses in the in primary distribution structures. In the process of network optimization, the constraints are of node voltages and radial arrangement of the network in which all loads must be energized. The proposed research results show that the voltage magnitudes of the week buses can be raised above 0.9p.u. Results also indicate that there is a

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significant upgrading of voltages of most of the buses. In the basic configuration power loss was 369.2558 kW, by using PSO method, loss is reduced to 238.2888 kW and the proposed work it will be reduced to 203.2318 kW at normal conditions. The energy loss reduction is 436.31 MWh.

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