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Network Reconfiguration of Distribution System for Maximum Loss Reduction Using Sine Cosine Algorithm

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ABSTRACT
In this manuscript, the network reconfiguration problem is resolved of open loop distribution systems with an objective of maximization of loss reduction. Distribution system plays an important role in supplying the electrical energy from power center to the end users via transmission coordination. The aim of the network reconfiguration is to reduce real power loss while satisfying all the operational constraints without islanding of any node. To decrease the system losses, the change of configuration in the meshed distribution system by switching operation with tie and sectional switches, while maintaining radial structure. A population based algorithm is called Sine Cosine Algorithm (SCA) is proposed for global optimization. The SCA algorithm is accomplished with standard 16-bus and 69-bus systems and outcomes proves the effectiveness of the proposed method.
Keywords: Loss Reduction, Sine Cosine Algorithm, Real Power Loss, Radial nature, Step by Step Reconfiguration, Voltage Profile.

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I. INTRODUCTION

Electricity has turn out to be a essential component of every house through distribution networks, in which power moves over longer distances from the source, which is usually situated at places which are at quite a distance from the residential regions due to geographical factors and pollution on a neighborhood. Network reconfiguration is a way to open some sectional switches and closing some tie switches. Reconfiguration has been dealt for last two decades with an aim to decrease power loss, to stabilize loads and to improve voltage profile, etc.

Network reconfiguration refers to the closing and opening of switches in a power distribution system in order to revise the network topology from time to time. Thus, the power flow from the main substation to the consumers may significantly improve by transferring the loads from one feeder to another. Depending on the current loading conditions, reconfiguration may become essential in order to remove the excess of loads on specific components like transformers or branch sections.

Civanlar [1] presented feeder reconfiguration and explains clearly how the configuration is modified in step by step process based on the changes in loss with minimum efforts. Sarma [2] explained a new technique for feeder reconfiguration of the tree structure for service restoration and it depends on the location and type of fault occurs in the original and reduced network. Kothari [3] described the network reconfiguration and the impacts of open loop structures using a multi-objective approach. Rudnik [4] proposed a methodology to reconfiguration to balance the loads. A power summation method used for power loss and it requires less computational time. Kashem [5] described a system reconfiguration for maximum on-line voltage stability solved by ANN which is trained using Conjugate Gradient Descent Back Propagation Algorithm and tested by daily load curves.

Yuji [6] presented tabu search for reconfiguration of an open loop radial distribution network with distributed generators to decrease the total line losses subjected to the line or transformer capacity and voltage constraint. Damodar Reddy [7] explained a fuzzy multi-objective approach for the capacitor placement of the reconfigured network to reduce losses. Hamouda [8] proposed improved method of load flow and it takes less computational time. Gupta [9] described an adaptive PSO of a network reconfiguration problem for reduction in power losses. Suhaib [10] proposed optimal reconfiguration by GSA with an objective of reducing I^2R losses.

Mirjalili[11], proposed novel nature inspired algorithm is called Sine Cosine Algorithm (SCA) which is used for global optimization. Sudhakar Reddy [12-15] described the dragonfly algorithm (DFA), PSO, ALO and GWO algorithms for network reconfiguration with an objective of reduction in loss using simultaneous switching Method. Suyanto [16] described a Modified Backward Forward method to capture the complexities of unbalanced three phase distribution system for improvement of voltage profile. Archana [17] proposed a modified Teaching learning based optimization (MTLBO) algorithm for network reconfiguration of the distribution system with an intention of reduction of operational cost.

The main contribution of this paper is to solve the reconfiguration problem using step by step switching to modify open loop distribution networks for lowest losses. A backward-forward power flow method is used for system loss calculation, which is explained in the next section.

II. PROBLEM FORMULATION

2.1 Calculation of load current

The complex power injected into the bus n is given [18] by

$$S_{L,n} = P_{L,n} + jQ_{L,n} = V_n . I_{L,n}^{*} \qquad (1)$$

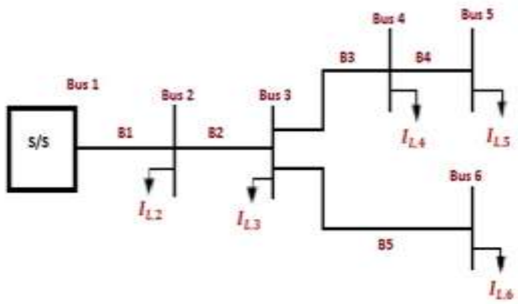

Fig. 1: A Sample 6-bus radial distribution system

The load current at any bus n is given by

$$I_{L,n} = \left(\frac{P_n + jQ_n}{V_n} \right)^{*} = \frac{P_n - jQ_n}{V_n^{*}} \qquad (2)$$

2.2 Formation of BIBC matrix

The relation [17] between load currents and branch currents can be found by using KCL equations of Fig. 1 are as follows.

$$I_{B1} = I_{L2} + I_{L3} + I_{L4} + I_{L5} + I_{L6} \qquad (3)$$

$$I_{B2} = I_{L3} + I_{L4} + I_{L5} + I_{L6} \qquad (4)$$

$$I_{B3} = I_{L4} + I_{L5} \qquad (5)$$

$$I_{B4} = I_{L5} \qquad (6)$$

$$I_{B5} = I_{L6} \qquad (7)$$

Thus, the relationship between load currents and branch currents can be expressed in matrix form as shown below.

$$[I_B] = [BIBC][I_L] \qquad (8)$$

2.3 Forward sweep

The receiving end voltages can be calculated by forward sweeping across the line by subtracting the line section drop from the sending end voltages of the line section.

$$V_q(k) = V_p(k) - I_B(k) * Z_p(k) \qquad (9)$$

2.4 Radial Structure

All loads must be connected to the supply node through altered ways while switching operation. According to graph theory a tree satisfies the subsequent equation.

$$N_{br} = N_{no} - 1 \qquad (10)$$

2.5 Power losses

The power losses in the distribution systems are real power loss and reactive power loss. The total real power loss in a balanced radial distribution system consisting of b branches can be written as

$$P_{LT} = \sum_{k=1}^{B} I_k^2 . R_k \qquad (11)$$

2.6 Objective Function

The objective function of the problem is formulated to exploit the power loss reduction in the radial distributed system, which is given by

$$Fitness\_Function = \min\{P_{Loss}\} \qquad (12)$$

III. STEP BY STEP RECONFIGURATION

Reconfiguration is defined as changing the structure of the system to reduce the total system loss in step by step manner. The primary switches are opened for 16-bus system is {14, 15, 16}. In the present work, the loop vectors for network reconfiguration by using possible switching operation, which is shown in Table 1. From these vectors, the best switching corresponding to each loop by considering real and reactive power loss and minimum voltage constraints is given in Table 2.

Table 1. Loop Vectors of 16-bus system

Test System	**SW_1**	**SW_2**	**SW_3**
16-bus system	14	15	16
	2	6	3
	8	12	4
	7	--	11
	--	--	13

Table 2. Switching Loops corresponding to step by step Reconfiguration

Test System	Switching Loops				
16-Bus	14	2	8		
	15	6	--		
	16	--	--		
69-Bus	72	55	56	57	58
	71	11	12	--	--
	73	61	--	--	--
	69	--	--	--	--
	70	17	--	--	--

IV. PROPOSED SINE COSINE ALGORITHM

4.1 Introduction

A novel population based optimization is called Sine Cosine Algorithm (SCA) [11] was implemented in 2016 for solving different problems. SCA is a population based optimization techniques start the optimization process with a set of random solutions. This random set is evaluated repeatedly by an objective function and improved with a set of rules. Since population based optimization techniques appear for the optima of optimization problems stochastically, there is no guarantee of finding a solution in a single iteration. However, with adequate number of random solutions and optimization steps, the probability of finding the global optimum increases.

The optimization process is classified into two phases, i.e., exploration and exploitation. In the earlier phase, an optimization algorithm combines the random solutions in the set of solutions suddenly with a high rate of randomness to locate the capable regions of the search space. In the exploitation phase, however, there are small changes in the random solutions, and random deviations are considerably less than those in the exploration phase which is shown in Fig. 2. SCA algorithm should be able to balance exploration and exploitation to find the promising regions of the search space and finally to reach the global best which is shown in Fig. 3. In order to balance exploration and exploitation, the range of sine and cosine in Eq.(13) is modified adaptively by using the following equation $r_1 < 1$.

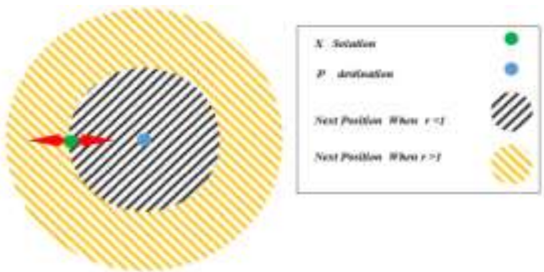

Fig. 2. Effects of Sine and Cosine towards the next position

Different regions of the search space are explored when the sine and cosine functions return a value greater than 1 or less than -1. The SCA algorithm smoothly transits from exploration to exploitation using the adaptive range change in the sine and cosine functions. The best approximations of the global optimum are stored in a variable at the destination point and never get lost during optimization [11].

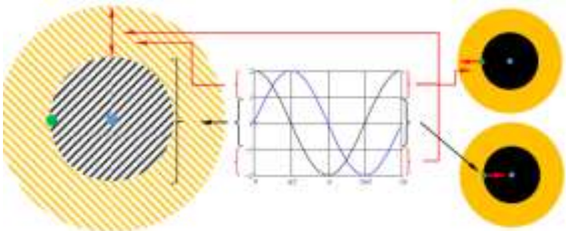

Fig. 3. Sine and Cosine with in range [-2,2] of solution to go around or beyond the destination

In this work, the following position updating equations is designed for both phases.

$$X_i^{it+1} = X_i^{it} + r_1 * \sin(r_2) * \left| r_3 P_i^{it} - X_i^{it} \right| \qquad (13)$$

$$X_i^{it+1} = X_i^{it} + r_1 * \cos(r_2) * \left| r_3 P_i^{it} - X_i^{it} \right| \qquad (14)$$

The above two equations are combined to be used as follows eq. (14).

$$X_i^{t+1} = \begin{cases} X_i^t + \left(r_1 * \sin(r_2) * abs\left(r_3 * Dest\_Pos(k) - X_i^t\right)\right), when, r_4 < 0.5 \\ X_i^t + \left(r_1 * \cos(r_2) * abs\left(r_3 * Dest\_Pos(k) - X_i^t\right)\right), when, r_4 \geq 0.5 \end{cases} \qquad (15)$$

4.2 Implementation of the Projected SCA Technique

Step 1: Initialize the parameters, i.e., search agents=50, number of iterations=500, destination position with size of 1 x dim and destination fitness as infinity.

Step 2: Set boundaries to the parameters that are to be optimized.

Step 3: Initialize lower and upper boundaries and the set of random solutions to the parameters.

Step 4: The optimal switching selection of network reconfiguration is achieved based on destination position.

Step 5: Run the basic load flow to acquire the true power or line losses and voltage profile before optimization.

Step 6: Estimate the fitness of the first set and find the best one and assigned to objective values.

Step 7: Set iteration count and generate the random variables by the following equation.

$$r_1 = a - C_{it} * \left(\frac{a}{T_{Nit}} \right) \quad \left. \begin{array}{l} r_3 = 2 * rand \\ r_4 = rand() \end{array} \right\} \qquad (16)$$
$$r_2 = 2 * Pi * rand()$$

Here, r_1 is decreasing linearly from *a=2* to *0*. Where C_{it} is the current iteration number; T_{N-it} is the maximum number of iterations; rand is creates arbitrary variables in between 0 and 1.

Step 8: Check if the solutions are going outside the search space and bring back them.

Step 9: Revise the position of solutions with respect to destination.

Step 10: Limiting the particle positions within boundary. Consider the objective values as active power loss for evaluation.

Step 11: Update the destination fitness, if there is a better solution.

Step 12: Repeat the same process from step 7 to 11 as until the destination position terminates to achieve best score.

Step 13: Display the best score of search agents which gives the optimum objective value with respect to best destination position

V. RESULTS

In order to demonstrate the efficacy of the proposed SCA technique is tested on standard 16-bus and 69-bus systems.

5.1 Standard 16-Bus test system

A 100MVA, 23KV test system [12] with 16 branches, 13 sectionalizing switches and 3 tie switches as shown in fig 4. The simulation results of 16-bus system are shown in Table 3.

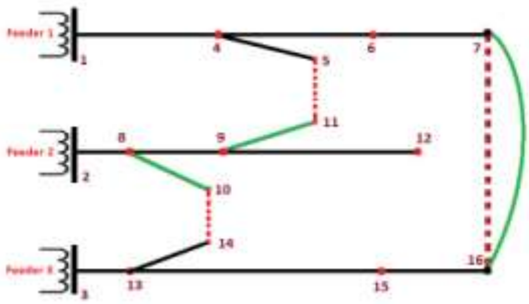

Fig. 4: Step By Step Reconfiguration of 16 bus test system

Table 3. Simulation Results of 16-bus system

Parameters	Original Network	After Network Reconfiguration
Switches open	14, 15, 16	8, 6, 16
Real power loss, kW	511.4356	466.1266
Minimum voltage	0.9693	0.9716
Location of V_{min}	12	12
Loss Reduction	----	8.86 %

In the primary configuration, power loss was **511.4356 kW** and after reconfiguration, power loss is reduced to **466.1266 kW**. The maximum reduction in real power loss is 45.3090 kW. The tie switches of original network represented as dotted lines are of red color and opened switches of optimal reconfiguration are of green color solid lines, which are shown in Fig 4.

5.2 Standard 69-bus test system

The configuration of the 100MVA, 12.66kV test system [7, 16] with 73 branches, 68 sectionalizing switches and 5 tie switches as shown in fig 5. The total substation loads for the basic configuration are 3802.2 kW and 2.6946 kVAr. The simulation results of 69-bus system are presented in Table 5.

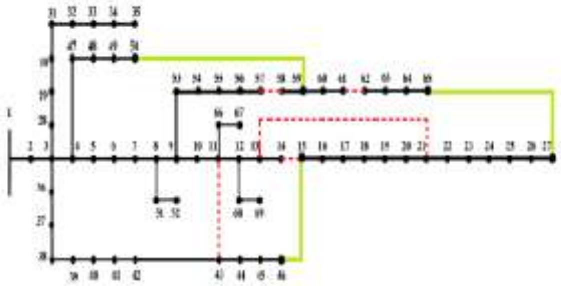

Fig. 5: Step By Step Switching of 69-bus test system

Table 4. Simulation Results of 69-bus system

Parameters	Original Network	After Network Reconfiguration
Switches open	69, 70, 71, 72, 73	12, 55, 61, 69, 70
Real power loss, kW	225.0044	99.8206
Minimum voltage	0.9092 p.u	0.9428 p.u
Location of V_{min}	65	61
Loss Reduction	----	55.64 %

In the original network, power loss was **225.0044kW** and after reconfiguration by using the sine cosine algorithm, power loss is reduced to **99.8206kW.** The comparison results of 69-bus system which is revealed in Table 5.

Table 5. Comparison Results of 69-bus system

Parameters	Ref [7]	Proposed SCA
Real loss, kW (Before RCG)	225.0044	225.0044
Vmin, p.u (Before RCG)	0.9092@65	0.9092@65
Switches open	14,55,62,69,70	12,55,61,69,70
Real loss, kW (After RCG)	100.6851	99.8206
Vmin, p.u (After RCG)	0.9414@61	0.9428@61
Loss Reduction	55.25 %	55.64 %

VI. CONCLUSION

In this paper, proposed Sine Cosine Algorithm, (SCA) algorithm as a new technique for reconfiguration of distribution system. In the proposed work, SCA technique is used to find the optimal configuration route by fulfilling all constraints in step by step process. The effectiveness of the proposed SCA algorithm is tested on the standard 16-bus and 69-bus systems. By step by step switching, the reduced active power loss is 8.86% for 16-bus and 55.64% for 69-bus systems respectively. The results obtained during simulation demonstrateed that the proposed SCA algorithm is capable of finding an optimal solution.

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REFERENCES

[1] S. Civanlar, J. Grainger, H. Yin, and S. Lee, "Distribution feeder reconfiguration for loss reduction", IEEE Trans. on Power Delivery, Vol.3, No.3, pp.1217–1223, July, 1988.

[2] N.D.R.Sarma, V.C.Prasad, K.S.Prakasa Rao, V.Sankar, "A new network reconfiguration technique for service restoration in distribution networks", IEEE Trans. on Power Delivery, Vol.9, No.4, pp.1936-1942, October, 1994.

[3] D.Das, D.P.Kothari and A.Kalam, "Simple and efficient method for load flow solution of Radial distribution networks", Electrical Power & Energy Systems, vol.17, no.5, pp.335-346, 1995.

[4] Hugh Rudnick, Ildefonso Harnisch, Raúl Sanhueza, "Reconfiguration of electric distribution systems", Revista Facultad De Ingenieria, Chile, Vol.4, 1997.

[5] M.A. Kashem, V.Ganapathy, G.B.Jasmon, "On line Network Reconfiguration for Enhancement of Voltage Stability in Distribution Systems Using Artificial Neural Networks", Electric Power Components and Systems, Taylor & Francis, 29:4, pp.361-373, 2001.

[6] Yuji Mishima, Koichi Nara, Taiji Satoh, Takamitsu Ito, "Method for Minimum-Loss Reconfiguration of Distribution System by Tabu Search", Electrical Engineering in Japan, Vol. 152, No. 2, 2005 p.p. 1149-1155, March - 2005.

[7] M. Damodar Reddy, Prof. V.C.Veera Reddy "A two-stage methodology of optimal capacitor placement for the reconfigured network", Indian Journal of Engineering and Material Sciences, Vol-17, p.p. 105-112, 2008.

[8] Abdellatif Hamouda, Khaled Zehar, "Improved algorithm for radial distribution networks load flow solution", Electrical Power and Energy Systems, 33, pp.509-514, 2011.

[9] Nikhil Gupta, Anil Swarnkar, K. R. Niazi, "Reconfiguration of Distribution Systems for Real Power Loss Minimization Using Adaptive Particle Swarm Optimization", Electric Power Components and Systems, Taylor & Francis, 39:4, pp.317-330, 2011.

[10] Y. Mohamed Shuaib, M. Surya Kalavathi, C. Christober Asir Rajan, "Optimal Reconfiguration in Radial Distribution System Using Gravitational Search Algorithm", Electric Power Components and Systems, 42:7, pp.703-715, 2014.

[11] Seyedali Mirjalili "SCA: A Sine Cosine Algorithm for solving optimization problems", Knowledge-Based Systems (2016), doi:

[12] A. V. Sudhakara Reddy, Prof. M. Damodar Reddy, "Optimization of distribution network reconfiguration using dragonfly algorithm", Journal of Electrical Engineering, Vol.16, Edition.4, No.30, pp.273-282, ISSN:1582-4594, Mar-2017.

[13] A. V. Sudhakara Reddy, Prof. M. Damodar Reddy, "Optimization of network reconfiguration by using Particle swarm optimization", IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Vol.4, pp. 1-6, July 2016.

[14] A. V. Sudhakara Reddy, Prof. M. Damodar Reddy, "Optimal Capacitor Allocation for the Reconfigured Network using Ant Lion Optimization Algorithm", International Journal of Applied Engineering Research, 12(12), pp.3084-3089.

[15] A.V.Sudhakara Reddy, M. Damodar Reddy, M. Satish Kumar Reddy (2017), "Network Reconfiguration of Primary Distribution System Using GWO Algorithm", International Journal of Electrical and Computer Engineering (IJECE) 7(6) 2017.

[16] Suyanto, Citra Rahmadhani, Ontoseno Penangsang, Adi Soeprijanto, "Power flow development based on the modified backward-forward for voltage profile improvement of distribution system",

IJECE, Vol. 6, No. 5, pp.2005-2014, Oct, 2016.
[17] Archana, Deepak Kumar, Vikash Kumar Gupta "Optimal Reconfiguration of Primary power Distribution System using Modified Teaching Learning based Optimization Algorithm", IEEE, 2016.

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