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Optimization of Distributed Generation using Elephant Herding Optimization (EHO) Techniques and Improvement in Multi-Objective Function

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Abstract: In Power System the Distribution network has the maximal no. of losses, basically these losses occurs in distribution system due to high concentration of inductive loads and demand .The placement of distributed generation resources and shunt compensation capacitors are used to one of the method for reducing losses in power system. But in this paper Distribution System, Distributed Generators are frequently used to provide active and reactive power for reducing active power losses and improves voltage profile So, proper installation of Distributed generators are necessary with optimal size and site. For DG installation in distribution system used some parameter like: DG location, DG size, Capacity and Numbers of DG units, type of system connection, DG technology etc. The power imparts from DG units located near to load centre provide an opportunity for system power loss reduction ,improvement in voltage stability and voltage profile , environmental friendliness and increasing reliability. In this paper presents Elephant Herding Optimization Techniques for finding Optimal Size and Site of DG in Radial distribution system .The main Objectives of this technique is Reduction in active power losses ,better voltage profile and Improvement in voltage stability index with operating security constraints in radial distribution network and performed in MATLAB R2015a Software . The proposed EHO techniques implemented for 33- bus and 69-bus standard test radial distribution system.

Keywords: EHO (Elephant Herding Optimization), VSI (Voltage Stability Index) , DG (Distributed Generation), RDS (Radial Distribution System), RDN (Radial Distribution Network), MOF (Multi-Objective Function), DER(Distributed Energy Resources), DS (Distribution System) .

I. INTRODUCTION

The Electrical Power System used in the past time was conventional centralized generation units ranges from 100MW to GW at remote location connected to loads with availability of renewable resources but as an alternative of using conventional generation units , now a day's distributed generator is used recently developed technology ranges from few watts to MW located nearby load centre with distributed Energy resources and DG technologies (like PV system ,wind turbines ,micro-turbines , fuel cells and battery system , combustion gas turbines etc.) [1][18].Generally the Distribution System uses radial and meshed (or network) type in rural and urban areas simultaneously with properly designed generation units. These generation units can distinctively effects on power system performances like power flow losses, voltage profile, voltage stability and reliability. The effects may be either positive or negative according to using DG technology and distribution system operating characteristics. Positive effect basically supported to electrical power system i.e. considered as improvement in system stability and reliability, better voltage profile, reduction in losses and environmental benefits etc. [2].For the Number of Electrical network user (or customer) increases rapidly with time also rise in network losses so, proper designing and utilization of network provided by distribution companies. In distribution system DG changes power flow and also changes the power losses. [3][4].Conventionally, placement of Distributed Generation and Capacitor are in power system to resituate for voltage profile improvement, power loss reduction and voltage stability improvement.[5].DG mainly classified in four types according to power flow i.e. shown in below :-

(A).DG supplying only active power (P.F. DG=unity, examples:-fuel cells, battery storage system and micro turbines)

(B).DG supplying only reactive power (P.F. DG =zero, examples:-Synchronous Compensators, KVAR and capacitors)

(C).DG inserting both active and reactive power (0<P.F.DG <1/+ve, examples:-Synchronous Generators)

(D).DG supplying active and drawing reactive power (0<P.F.<1/-ve, examples: - Wind Turbines connected with Induction Generator)[6].

In distribution network optimal placement defines as an optimal size and location used for improvement in system performances with single and multi-objective functions. Optimal placement of DG in Distributed network is a biggest problem for researchers. For Optimal Placement researchers have invented algorithms and methods to solve this problem [7].

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But In Distribution System capacitor placement not uses distributed energy resources because in our country resources scattered naturally with small sizes. Transmission and Distribution costs are reduced when DG unit connected nearby consumer's .So using EHO for optimal sizing and location of distributed generation with better voltage profile, improvement in voltage stability index, reduction in active power losses and high penetration level of DG discuss in this paper. The locations of DG in distribution network determined on the basis of active power supply by the nodes in system [8].

II. PAGE LAYOUT

In this paper sequentionally defines the problem formulation for single objective function (like: reduction in active power losses, improvement in node voltage fluctuation and maximization of voltage stability index) and multi-objective function (like: system operating constraints), EHO method, Flow chart for EHO, For 33-bus and 69-bus System Case Studies, Fig of node voltage profile, Table respectively, Applications of EHO, Conclusion, References etc.

III.PROBLEM FORMULATION

This Section defined the objective function with single and multi objective, system operating constraints for optimal placement of DG using Elephant Herding Optimization Techniques [9]. In this study following assumptions to be taken into account i.e.-

A. Unity Power Factor of the DGs.
B. Balanced Radial Distribution network to be considered.
C. Load level to be considered as Nominal.
D. DER is not considered uncertainty [10].

1) Objective Function: For DG placement in Radial Distribution System the objective function is reduction in active power losses, Improvement in node voltage fluctuation, maximization of voltage stability index and DG penetration with all system operating constraints defined in below:-

a) Single Objective Function: Generally this objective function is defined by a single number of function like: reduction in active power losses ,improvement in node voltage fluctuation ,maximization of voltage stability index etc.

i) Reduction in Active Power Losses: During power dispatch in distribution system maximum no. of power losses take place in power system. So, the main aim of power system is to be power distributed at minimum losses and considered as objective of system:-

F_1=Minimum (P_{Loss}) (1)

In radial distribution system where P_{Loss} is active power losses and given by:-

$$P_{Loss} = \sum_{i=1}^{N} a_{ij}(P_i P_j + Q_i Q_j) + b_{ij}(Q_i P_j + P_i Q_j \quad (2)$$

Where :- $Loss\ co-efficients$ (a_{ij} $=r_{ij}\cos(\delta_i-\delta_j)/V_iV_j$,$b_{ij}=r_{ij}\sin(\delta_i-\delta_j)/V_iV_j$),P_i= injected active power at node i ,Q_i= injected reactive power at node i ,N=total numbers of nodes in system ,r_{ij}=resistance of branch between i and j ,δ_i=Angle of ith node , V_i=voltage magnitude at ith node .

ii) Improvement in Node Voltage Fluctuation: The voltage quality measured across system nodes i.e. known as node voltage fluctuation. For improvement in node voltage fluctuation DG connected nearby load centre and considered as an objective function defined by:- $F_2 = \sum_{i=1}^{N}(V_i - V_{rated})^2$ (3)

iii) Maximization of Voltage Stability Index: In distribution system the improvement in node voltage deviation is not sufficient measure for security purposes .so the VSI is supported to maximize Voltage Stability Margin (VSM) of the system. Generally VSI is a capability to maintain voltage profile at increasing loading condition with permissible limits of nodes. For radial distribution network VSI is given by:-

$$F_3 = VSI_{ij} = V_j^4 - 4(P_i r_{ij} + Q_i x_{ij})V_j^2 - 4(P_i x_{ij} - Q_i r_{ij})^2 \quad (4)$$

b) Multi-objective Function: A number of functions to be optimized concurrently within various system constraints. Multi objective function combines reduction in active power losses, improvement in node voltage fluctuation and maximization of voltage stability index in this paper.

MOF = ($\alpha_1F_1+\alpha_2F_2+\alpha_3F_3$) (5)

Where: - function F_1 =reduction in active power losses, F_2 = improvement in node voltage fluctuation, F_3=maximization of voltage stability index with weight (penalty) co-efficient α_1=1, α_2=0.65, α_3=0.35.

2) *Operating System Constraints*: Following constraints are used in single and multi objective function described in below:-

a) *Equality Constraints*

i) *Power Balance Constraints:* Total active and reactive power supplied by DG with satisfying power balance constraints distinctively.

$$P_i = V_i \sum_{j=1}^{N} V_j Y_{ij} \cos(\theta_{ij} + \delta_j - \delta_i) \qquad \forall i \qquad (6)$$

$$Q_i = -V_i \sum_{j=1}^{N} V_j Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \qquad \forall i \qquad (7)$$

Where: θ_{ij}= Impedance angle between ith and jth node, Y_{ij} =Elements of Y bus matrix, V_i=Voltage at ith node and V_j =Voltage at jth node.

b) *Inequality Constraints*

i) *Thermal limits:*-The current at particular branches with allowable limits is defined as:-

$$I_{ij} \leq I_{ij}^{maximum} \qquad (8)$$

a. *Where:* I_{ij}=current flowing through ith and jth branch, $I_{ij}^{maximum}$ =maximum loading of distribution system connected between ith and jth node.

ii) *Bus Voltage Limits:*-In distribution system voltage constraints within upper and lower permissible limits of voltage imbalances at various nodes.

$$V_i^{minimum} < V_i < V_i^{maximum} \qquad (9)$$

a. *Where:* $V_i^{minimum}$ =minimum value of bus voltage limits i.e. 0.95 p.u.
$V_i^{maximum}$=maximum value of bus voltage limits i.e.1.05 p.u.

iii) *Active Power Limits:*-The active power limits of DG at ith bus with specified various limits is given by:-

$$P_{DG,i}^{minimum} \leq P_{DG,i} \leq P_{DG,i}^{maximum} \qquad \mathbf{(10)}$$

a. *Where:* $P_{DG,i}^{minimum}$ =minimum value of active power at ith bus of DG, $P_{DG,i}^{maximum}$ = maximum value of active power at ith bus of DG.

iv) *Reactive Power Limits:*-The reactive power limits of DG at ith bus with specified various limits is given by:-

$$Q_{DG,i}^{minimum} \leq Q_{DG,i} \leq Q_{DG,i}^{maximum} \qquad (11)$$

a. *Where:* $Q_{DG,i}^{minimum}$=minimum value of active power at ith bus of DG, $Q_{DG,i}^{maximum}$ = maximum value of active power at ith bus of DG [5][11].

v) *DG penetration limits:*-The Existing Distribution system is generally uses load 0.5MW, 3MW, 6MW, 10MW with this capacity 4KV, 12KV, 25KV, 34KV respectively. DG penetration with allowable limits is defined as:-

$$S_{DG} \leq S_{DG}^{maximum} \quad \forall i \qquad (12)$$

a. *Where:* $S_{DG}^{maximum}$=maximum allowable limits of DG can be placed at a single node [10].

IV. ELEPHANT HERDING OPTIMIZATION (EHO)

A newly developed nature inspired method i.e. EHO techniques proposed by Gai –Ge Wang et.al. In 2015.The principle inspired of this algorithm is “Herding behaviour of elephants” [12].

Elephant Herding Behaviour:-Generally on our land Elephants are one of the largest mammals .Traditionally American elephant and African elephant are two type species recognized .A long trunk is an indication of elephant and i.e. multi-uses like: holding objects, lifting water and breathing etc. Elephants are social animals in nature and Elephant herding combines the female elephant and claves. Each clan follows the matriarch (leader elephants).Female Elephant always selected to live together with their family groups but the male elephants isolated or not contact with their family groups when male elephants grow up and using low frequency vibrations they live in connect with their family groups. Basically two types operators used for this global optimization method that is clan updating and clan separating operator. The following rules used for this optimization method:-

1) The population of elephant is consists of some clans and fixed number of elephant or equal number of elephant in each clan to be considered.
2) In each clan elephant live together with leadership of matriarch and considered the fittest elephant in each clan.
3) Male elephant considered to be fixed number and isolated from their main family groups at a time of start of generation.

This Algorithm is mathematically modelled and classified into different steps which are shown in below section:-

Step:1-(Clan position update):-The matriarch and male elephant clasps the best and worse position in each clan and best and worse solution of each clan updated and given by :-

$$E_{new,cj,i} = E_{cj,i} + \alpha\left(E_{best,cj,i} - E_{cj,i}\right) \times rand \qquad (13)$$

Where $E_{cj,i}$=Present position of ith elephant in cjth clan, $E_{new,cj,i}$= New position of ith elephant in cjth clan, rand=random number between 0 and 1, α=scale factor between 0 and 1.

Step: 2-(In each clan position update of fittest elephant):-Matriarch or leader elephant is considered to be fittest elephant and updated this position given by:-

$$E_{new,cj,i} = \beta \times E_{center,cj} \qquad (14)$$

Where: - $\beta = scale\ factor\ between\ 0\ and\ 1$, $E_{center,cj} = \sum_{i=1}^{n} E_{cj,i}/n_z$, n_z=total no. of elephant in each clans , i=individual elephant in each clan.

Step: 3-(In each clan separating the worst elephant):- Male elephant or worst elephant separated from their family group in each clan and gives worst solution which is modifying by:-

$$E_{worst,cj,i} = E_{minimum} + (E_{maximum} - E_{minimum} + 1) \times r \qquad (15)$$

Where: - $E_{minimum}$=Minimum permissible limits for the each clan elephants, $E_{maximum}$= Maximum permissible limits for the each clan elephants, $E_{worst,cj,i}$=male or worst ith elephant in cjth clan, r=random number between 0 and 1.

Step: 4-(Check Convergence):-When Convergence criteria not satisfied then repeated step1 to step 3.

The Flow chart of EHO (Elephant Herding Optimization) technique in below fig.

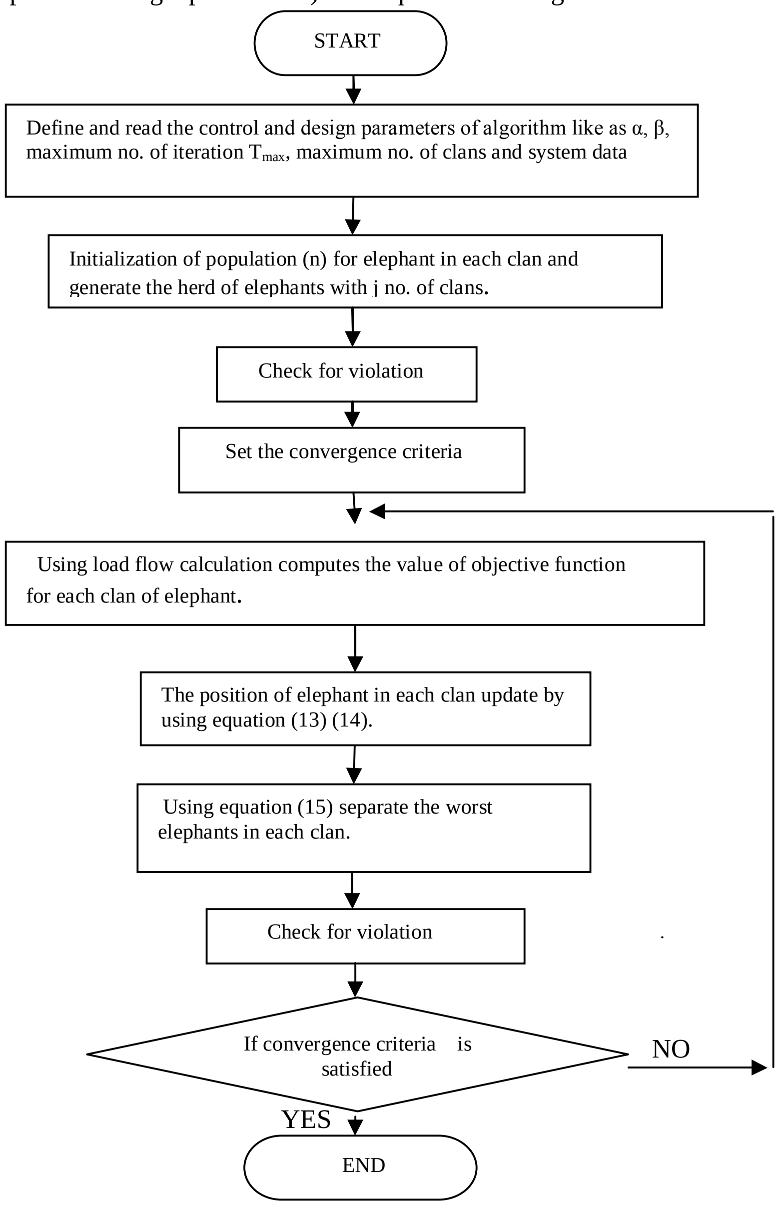

Fig. 1. flow chart of EHO (Elephant herding optimization) algorithm

V. SYSTEM CASE STUDIES

EHO method is applied on two 33-bus and 69-bus IEEE Standard test Distribution System .The Controlling Parameters used in this method for 33-bus radial distribution system are given by:- maximum number of iteration (T_{max})=100, α = 0.5(scaling factor),β=0.1(scaling factor),population size(n)=50 and 69-bus radial distribution system are given by:- maximum number of iteration (T_{max})=100, α = 0.5(scaling factor),β=0.1(scaling factor),population size(n)=150 . In this paper numerous optimization techniques provide for various case studies and compared simulation result and performance of EHO with other optimization techniques.

1) *System-1 Studies:*-For the optimal sizing and location problem of 33-bus radial distribution system used with suitable problem formulation and this solution .The simulation results attained are analysed and compared with different cases. In this method uses Active power demand=3.715MW, Reactive power demand=2.3000KVAr, Base Voltage=12.66KV for Systm-1 studies.

a) *Case-I (Base Case):*-For this case not used any type of DG and Table1. Combines the Optimal DG Site, Optimal DG Size, objective function values i.e.F_1,F_2,F_3, Multi-objective function values (using weight or penalty co-efficient) and DG Penetration.

b) *Case-II(Three DG Operated at Unity Power Factor (UPFs)):*-In this case three different nodes used for three DG installation in Distribution System .The simulation result attained by EHO method and compared to different existing method explained in Table1 in this paper. Table1 combines the Optimal DG Site, Optimal DG Size, objective function values i.e.F_1,F_2,F_3, Multi-objective function values (using weight or penalty co-efficient) and DG Penetration and Proposed method represented by bold values in this table. The Proposed EHO method compared to PSO, GA/PSO, TLBO, QOTLBO, GA with changes in objective function.

c) *Case-III (Four DG operated at Unity Power Factor):*- In this case four different nodes used for four DG installation in Distribution System .The simulation result attained by EHO method and compared to different existing method explained in Table1 in this paper. Table1 combines the Optimal DG Site, Optimal DG Size, objective function values i.e.F_1,F_2,F_3, Multi-objective function value (using weight or penalty co-efficient) and DG Penetration and Proposed method represented by bold values in this table. The Proposed EHO method compared to PSO, GA/PSO, IMOHS, GA with changes in objective function.

In this System Studies Case-II gives best or optimal solution as compared to Case-I and Case-III. Voltage Profile of system obtained better for all cases w.r.t. base case shown in Fig 2. And improves the value of voltage stability index for Case-II as compared to Case-I and Case-III.

2) *System-2 Studies:* For the optimal location and sizing problem of 69-bus radial distribution system used with suitable problem formulation and this solution .The simulation results attained are analysed and compared with different cases. In this method uses Active power demand=3.715MW, Reactive power demand=2.3000KVAr, Base Voltage=12.66KV for Systm-2 studies.

a) *Case-I (Base Case):*-For this case not used any type of DG and Table2. Combines the Optimal DG Site, Optimal DG Size, objective function values i.e.F_1,F_2,F_3, Multi-objective function values (using weight or penalty co-efficient) and DG Penetration.

b) *Case-II (Three DG Operated at Unity Power Factor (UPFs)):*-In this case three different nodes used for three DG installation in Distribution System .The simulation result attained by EHO method and compared to different existing method explained in Table2 in this paper. Table2 combines the Optimal DG Site, Optimal DG Size, objective function values i.e.F_1,F_2,F_3, Multi-objective function values (using weight or penalty co-efficient) and DG Penetration and Proposed method represented by bold values in this table. The Proposed EHO method compared to PSO, GA/PSO, TLBO, GA with changes in objective function.

In this System Studies Case-II gives best or optimal solution as compared to Case-I .Voltage Profile of system obtained better for all cases w.r.t. base case shown in Fig 3 and Improves the value of voltage stability index for Case-II as compared to Case-I.

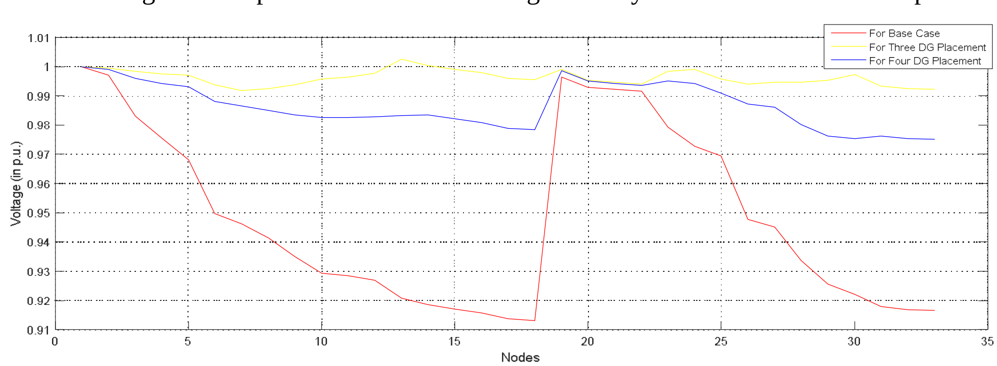

Fig. 2.System-1 Node Voltage Profile for different cases

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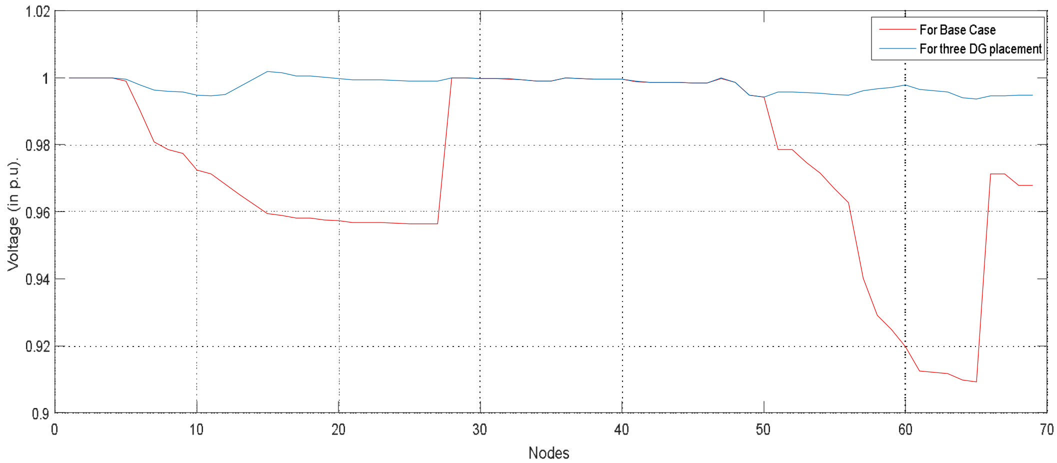

Fig.3. System-2 Node Voltage Profile for different cases

Table1. For IEEE 33-bus system with proposed EHO method compared to different method

Case	Used method	Optimal DG site	Optimal DG Size(MW)	Value of Objective Function			Multi-Objective Function	DG Penetration (in %)
				F1 (MW)	F2	F3		
I.	BASE CASE	—	—	0.2025	0.1170	0.6989	0.5232	0.00
II.	PSO	8,13,32	1.177,0.982,0.830	0.1053	0.0335	0.9256	0.4510	50.27
	GA/PSO	11,16,32	0.925,0.895,1.200	0.1034	0.0124	0.9508	0.4442	50.27
	TLBO	12,28,30	1.183,1.191,1.186	0.1247	0.0011	0.9503	0.4580	59.90
	QOTLBO	13,26,30	1.083,1.188,1.199	0.1034	0.0011	0.9530	0.4376	58.38
	GA	25,30,13	0.9090,1.6840,1.1658	0.0958	0.0007	0.9701	0.4359	53.76
	EHO	24,30,13	1.2630,1.6432,1.1400	0.0948	0.0006	0.9715	0.4353	57.92
III.	PSO	6,15,25,31	0.830,0.833,0.541,0.648	0.0713	0.0109	0.8776	0.3855	47.98
	GA/PSO	14,24,26,32	0.663,1.023,0.867,0.664	0.0682	0.0130	0.8903	0.3878	54.12
	IMOHS	6,14,24,31	0.937,0.667,1.012,0.731	0.0678	0.0111	0.8891	0.3862	56.31
	GA	7,15,24,31	0.8884,0.6810,0.9420,0.7760	0.0670	0.0080	0.9049	0.3889	47.02
	EHO	7,14,24,31	0.9802,0.6690,0.9698,0.7510	0.0667	0.0079	0.9058	0.3888	48.20

Table2. For IEEE 69-bus system with proposed EHO method compared to different method

Case	Used Method	Optimal DG Site	Optimal DG Size (MW)	Value of Objective Function			Multi-Objective Function	DG Penetration (in %)
				F1(MW)	F2	F3		
I.	BASE CASE	—	—	0.2274	0.0993	0.6870	0.5296	0.00
II.	PSO	17,61,63	0.9925,1.1998,0.7956	0.0832	0.0049	0.9676	0.4250	40.113
	GA/PSO	21,61,63	0.9105,1.1926,0.8849	0.0811	0.0031	0.9768	0.4249	40.115
	TLBO	13,61,62	1.0134,0.9901,1.1601	0.0821	0.0008	0.9745	0.4237	42.47
	GA	16,61,62	0.8002,1.17240.9974	0.0806	0.0006843	0.9784	0.4233	39.90
	EHO	15,60,61	0.7812,0.5197,1.6973	0.0800	0.0006432	0.9784	0.4229	40.29

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VI. APPLICATION OF EHO (ELEPHANT HERDING OPTIMIZATION)

Proposed EHO method also used for solving real world problems i.e. Dynamic Economic Dispatch Problem and Optimal Control of Non linear Stirred Tank Reactor. Both of problems explain in below section:-

1) *Dynamic Economic Dispatch(DED) Problem:* This problem considered the hourly dispatch problem and at a time problem fluctuates the power demand with passing hour and also defined the one day power generation schedule. Using Static Economic Load Problem for optimization of DED problem considered 24times dimensions.
2) *Optimal Control of Non linear Stirred Tank Reactor:* Standard test meta-heuristics algorithm used for a continuous stirred non-linear i.e. multi-model optimization problem .The first order chemical reaction for this process is mathematically modelled and given by:-

$$dx_1 = -(2+u)(x_1+0.25)+(x_2+0.5)\exp\left(\frac{25x_1}{x_1+2}\right) \quad (16)$$

And similarly for dx_2,

$$dx_2 = 0.5 - x_2 - (x_2+0.5)\exp\left(\frac{25x_1}{x_1+2}\right) \quad (17)$$

Where:-u(t)=Rate of flow of the cooling fluid, x_1=Steady state temperature for dimensionless quantity, x_2= deviation from dimensionless quantity at steady state concentration .To minimize the performance index determined the suitable value of u is given by:- $J = \int_0^{t_f=0.72}(x_1^2 + x_2^2 + 0.1u^2)dt$ (18)

VII. CONCLUSIONS

Elephant group is consists of Female, Male, Matriarch (leader elephant) and several claves in nature. The herding behaviour of elephant in nature classified in two operator i.e. clan updating and clan separating operator and also EHO is newly developed swarm optimization method for solving global optimization problems. In this paper proposed EHO method applied on 33-bus and 69-bus radial distribution system with solving of optimal location and sizing problem of DG. For 33-bus System with 3 DG placement Optimization technique is compared to GA,PSO,GA/PSO,TLBO,QOTLBO and33-bus System with 4 DG placement Optimization technique is compared to GA,PSO,GA/PSO,IMOHS . For 69-bus System with 3 DG placement Optimization technique is compared to GA, PSO, GA/PSO, TLBO, but proposed method is superior to other existing method for 33-bus and 69-bus system. Proposed EHO method gives reduction in active power losses and improvement in node voltage profile and voltage stability index as compared to before DG Installation when DG installed in Distribution system improvement in objective function and multi-objective functions. The best DG Site for 33-bus system at 3 DG placement is analysed by EHO method at nodes 24,30,13 with node capacity 1.2630,1.6430,1.1400, than reduces active power from 0.2025 MW to 0.0948 MW and improves node voltage profile from 0.1170 p.u.to 0.0006 p.u. and also increases the value of voltage stability index i.e.0.6989 to 0.9715 at normal load condition. The best DG Site for 33-bus system at 4 DG placement is analysed by EHO method at nodes 7,14,24,31 with node capacity 0.9802,0.6690,0.9698,0.7510, than reduces active power from 0.2025 MW to 0.0667 MW and improves node voltage profile from 0.1170 p.u.to 0.0079 p.u. and also increases the value of voltage stability index i.e.0.6989 to 0.9058 at normal load condition. The best DG Site for 69-bus system at 3 DG placement is analysed by EHO method at nodes 15,60,61 with node capacity 0.7812,0.5197,1.6973, than reduces active power from 0.2247 MW to 0.0800 MW and improves node voltage profile from 0.0993p.u.to 0.0006432 p.u. and also increases the value of voltage stability index i.e.0.6870 to 0.9058 at normal load condition.

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