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MAXIMIZATION OF ECONOMY IN DISTRIBUTION NETWORKS WITH MOST FAVORABLE PLACEMENT OF TYPE-1 AND TYPE-2 DISTRIBUTED GENERATORS ALONG WITH REORGANIZATION USING PSO-WOA HYBRID OPTIMIZATION ALGORITHM

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ABSTRACT

Hybrid optimization is used to maximize the savings through reconfiguration, type-1 and type-2 distributed generators (DG) placement. The PSO and WOA are used for reconfiguration and DG placement respectively. The major objective for this algorithm is to maximize the economy by minimizing the loss, by including loss cost. The suggested algorithm is checked on two IEEE radial distribution system (RDS) which are IEEE 33 RDS and IEEE 69 radial distribution network. The installation cost and maintenance of DG is included in objective of hybrid optimization while installation of DG along with reconfiguration and without reconfiguration.

Keywords: distributed generators, hybrid optimization, particle swarm optimization (PSO), radial distribution system, whale optimization Algorithm (WOA).

1. INTRODUCTION

Utilization of generated power is at the generation side in the reconfigured power system. The generators are called distributed generators, which are installed at distribution side. The generators (DGs). DGs are categorized to three types which compensates type 1, type II and type III, compensated watt power (kW), wattles power (kVaR) and apparent power (kVA) respectively. The distribution network is studied by wield load flow investigation. The radial character of the network is not suitable to use, commercial load flow techniques like Gauss-seidel method, Newton Raphson method which are called commercial load flows. So, the RDS is analyzed by wield forward/ backward sweep load flow. The major application of load flows is determining voltage profile, losses and branch currents of the system. The losses of the network are affecting the total savings of the system as considered the cost for them. The losses of the system can be reduced by using compensated devices like static capacitor, DGs, D-STATCOM etc. The losses of the system are reduced by compensating devices with the cost of installation and maintenance. The losses of the system are also reduced without any cost by reconfiguration. Reorganize issue, using a branch approach with optimization of bounded type was suggested initially by Merlin *et.al.* [1]. It is avery prolonged approach as probable device layout, where line parts situated furnished with toggles. An algorithm established on the heuristic guidelines and stupid multi-target technique to optimize the network [2]. Major consequence in the proposed algorithm is for the selection of membership functions of the targets are not re5ported [3]. Genetic algorithm (GA) exterminates the problem with minimum loss organization for distribution installation [3]. An algorithm to resolve reconfiguration of network issue with optimal combinations of switches combinely in the network was proposed to diminish power losses [4]. The placement of capacitor to reorganize RDS was proposed using PSO [5]. Also, Harmony Search Algorithm (HSA) was proposed to resolve allocation crisis of system network restructuring in occurrence of DG [6]. A survey on unified tracking and improvement voltage control calculations has been introduced in [7]. GA and enhanced joined strategy for switch-trade in a DNR issue was used to accomplish a base misfortune within the sight of DGs [8]. The comparative study of DGs is proposed in [9]. The real power compensation DGs are designed with PV system which are designed with inverter [10]. The preferable placement and accurate size of DG in RDS are critical requirements for the minimization of losses in the system [11]. The increment of losses in system will influence the bus voltage, which motivates the usage of voltage regulation through energy storage system [12]. The different load models of the distributions are studied and optimal location of DG is proposed with different optimizing techniques [13]. In modified plant growth simulation method is used for finest placement of DG with reconfiguration [14]. The authors majorly focus on enhancing the voltage profile with best possible size of DG. The methodology is verified with IEEE 33 bus RDS for loss minimization [15]. In GA is used for finest location of DG and static Var compensator to control the watt power sufferers and enhance the voltage report. The static Var compensator is also performing the similar task without dynamic components. The installation cost of DG is higher than static Var compensator, which needs expertise person to control [16]. In a comprehensive review is provided for DG which is designed using Photovoltaic (PV) cells. The work has accurate solutions for improving voltage and reducing losses through green energy DGs. In the objective function of optimization techniques used by this work are conventional algorithms

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[17]. In multi-objective objective function is used for overall reduction of investment cost for switched and dynamic capacitors along with reconfiguration. The cost of the system, is converted in to energy as the loss cost has the coefficient on $/kWh. In this work, real 2313-node distribution system is used to verify the accomplishment of suggested optimization method [18]. In consistent voltage distribution based practical reconfiguration algorithm is detailed to analyze the distribution networks for reducing the losses and voltage improvement. DGs are also considered along with reconfiguration in this work [19]. In DG and shunt capacitor, are used to compensate the RDS from active and wattles power losses. Type-1 DG used to compensate the watt power load at the placed bus whereas static capacitor is used to inject the reactive currents at the installed bus. The static capacitor similarly performs like type-2 DG, but with constant injection of reactive currents

The literature detailed up to now is illustrated only one heuristic optimization schemes for reconfiguration with preferable placement and accurate size of DG. In this paper different optimization algorithms such as PSO for reconfiguration, WOA for preferable position and accurate size of the DG. The paper is divided in to four sections, such as second section load flow is detailed, section three distribution system reconfiguration is discussed and section four comparative analysis of different optimization techniques is proposed and section five results are detailed with conclusions.

2. METHODOLOGY

For any study in the power system the load flows are the primary phase. The study like power quality, voltage quality, conductor thermal constraints, watt and reactive power losses. The load flow analysis during this study is employed a well-known algorithmic program known as forward/ backward sweep algorithm. The algorithmic program, load flow is started with assumption of flat voltage profile of the buses.

The currents are determined from the load by using branch impedances and flat voltage profile in reverse direction, the voltage of the buses is in forward way and this algorithm is called forward / backward sweep algorithm. RDS reconfiguration hinge on the number of loops to the system. The system loops are displaced by opening a branch called tie-line switch and the branches of the system which are not set the loop called main line switch or sectionalized buttons. The numbers of tie-line buttons are identical to number of tie line switches. The proper combination of tie-line switches and sectionalized switches without disturbing the radial nature of distribution system. In case of practical distribution systems, reorganization is much difficult to process with trial and error method. Hence an alternative approach is required for elevated practical bus systems. Since the improvement technique is employed, so target function has to outline. This work focuses on reduction of losses for reconfiguration. The losses of the system further reduced by installing the compensating devices with in eye for enhancement of savings. This segment is additionally partitioned into three like load flows, PSO and WOA optimization approach with their algorithms and flow charts.

2.1 Development of BIBC Matrix:

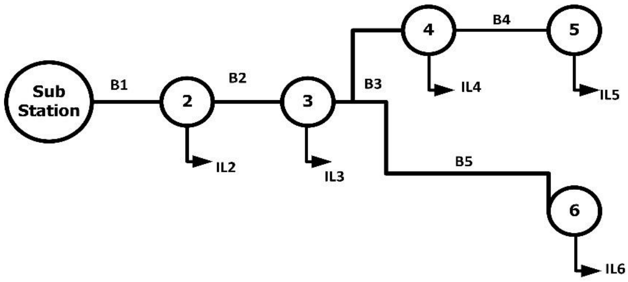

Figure-1. Sample 6-node RDS.

From figure 1 using KCL,

$$I_{B5} = I_{L6} \quad (1)$$

$$I_{B4} = I_{L5} \quad (2)$$

$$I_{B3} = I_{L4} + I_{L5} \quad (3)$$

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

$$I_{B1} = I_{L2} + I_{L3} + I_{L4} + I_{L5} + I_{L6} \quad (5)$$

Thus, correlation of line and load currents in matrix as

$$[I_B] = [BIBC][I_L] \quad (6)$$

The $V_{res\text{-}end}$ can be calculated using advance sweep

$$V_q(k) = V_p(k) - I_B(k) * Z_B(k) \quad (7)$$

$$P_{L,T} = \sum_{k=1}^{B} I_k^2 . R_k \quad (8)$$

Where
$P_{L,T}$ = Transmission losses (kW).
R_k = k_{th} branch resistance (ohm/km).
V_q = q^{th} bus voltage (V)
I_B = B^{th} branch current.
I_L = L^{th} bus current.
Z_B = Impedance measurement at B_{th} branch (ohm/km).

2.1.1 Reorganization network

DNR is a most conventional approach which minimizes the network disturbances. Mainly in distribution structure, the reorganization crisis is to locate most exceptional radial network pattern that offers smallest amount of power loss at the same time as employing limitations.

For standard 33 node radial system, table1 gives the no of system possible loops.

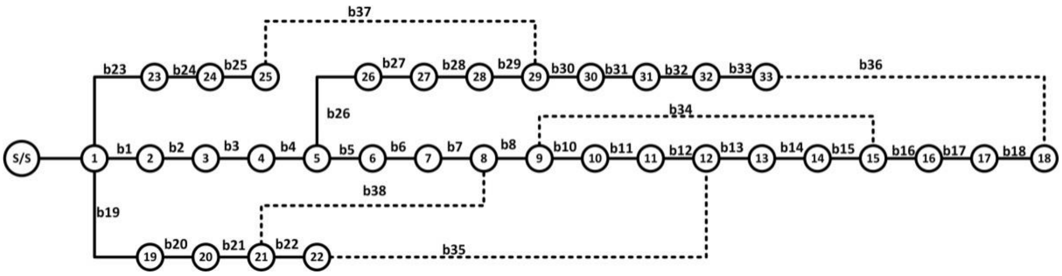

Figure-2. 33 node RDS along with Tie line switches.

Table-1. Number of possible loops for standard 33 node rds [20].

Node. No	L1	L2	L3	L4	L5
1	25	7	15	21	12
2	23	8	18	22	13
3	24	5	6	10	14
4	29	6	16	9	15
5	26	3	27	8	10
6	27	4	7	11	9
7	28	19	29	12	11
8	5	21	17		
9	6	20	28		
10	3	2	26		
11	4		32		
12			31		
13			30		
14			9		
15			8		
16			33		

Table-1 illustrates the formation of a loop with grouping of tie line links. Load stabilizing in to the radial distribution network can be achieved by choosing suitable position of tie line links as the nodes are packed with constant. Hence, it is imperative to choose a correct location of tie line link. For practical radial systems, selection of tie line link is very tough as it has larger nodes. The reasonable of the open buttons could turn out to be extremely simpler by acquiring this system predicament to the heuristic optimization techniques. The hybridization of such improvement procedures used to give ideal outcomes contrasted with natural streamlining strategies, for example, GA, PSO, and so forth. Hence, this work focuses on combinations of PSO and WOA algorithms to optimize type-I & II DG reorganization and most favorable position for utmost economy

2.2 Particle Swarm Optimization (PSO)

In a few nonlinear issues, it is a primary swarm based strategy as GA has its individual cut-off points on transformation, crossing over occurrence, time and code unpredictability. GA is to a great extent subject to the quantity of chromosomes can be expressly focused to boost the issue. Generally engineering regulations specifically are of a nonlinear. Phrasings that are utilized in PSO are particles, generations, and inertia in least and utmost, initial and final velocities. The particles are inhabited with the arbitrary qualities separate to imperatives and confinements. The particles are replacements in the target work in every origination. Every origination the particles are refreshed with least inertia, utmost inertia, first and last velocities. So, the algorithm for PSO is given as follows.

2.2.1 Algorithm

a) Initialize the PSO parameters such as least inertia (M_{min}), utmost inertia (M_{max}), first and last velocities (V_{i} and V_{f}).

b) Populate the particles within the constraints.

$$U = \begin{bmatrix} u11 & \cdots & u1d \\ \vdots & \ddots & \vdots \\ up1 & \cdots & upd \end{bmatrix} \quad (9)$$

Where,

u represents the particle
u11 represents particle at 1st row and 1st column
uld represents parttcle at 1st row and dth column
p represents the number of particles
d represents dimension of the objective function for solving through PSO.

c) At first generation calculate objective function (f_{obj}) at every particle.

d) Calculate the minimum value from all particles at generations

e) Update the particles with inertia M.

U(Update)=M*X+V_i*rand(1)*(Pbest-U)+V_f*rand(1)*(Gbest -U) (10)

Where

$$M = M_{max} - \frac{(M_{max} - M_{min})}{(ng-1)}(iter - 1) \quad (11)$$

f) Increment the generation until maximum generations.

g) The optimum value is obtained at the end of maximum generations.

2.2.2 Whale Optimization Algorithm (WOA)

WOA is natures inspired algorithm which is likewise propelled from swarm-based algorithm. The significant idea driving swarm based improvement is looking for the food area. The area of food location is equivalent to swarm locations at improved spot. However, the phases of each swarm calculations are non-identical from their regular behavior of piercing for the food. In WOA likewise, dragons are called looking through operators, which changed the areas as per the food locations alongside getting away from predominant foes. Nomenclatures utilized in WOA are looking through specialists, greatest generations, partition, arrangement, union food source, adversary position. The algorithm of WOA is as follows:

Initialize all the WOA parameters.

Populate the searching agents with the variable's constraints of the objective function

$$S = \begin{bmatrix} w11 & \cdots & w1d \\ \vdots & \ddots & \vdots \\ wa1 & \cdots & wad \end{bmatrix} \quad (12)$$

Where
w represents searching agent.
w11 represents searching agents at 1st row and 1st column of the matrix
a represents numbers of searching agents
d represents dimension of the f_{obj} used in WOA.
While true
Calculate the F_{obj} for all searching agents' values
Update position of searching agents with small changes along with other parameters.
Determine the optimum f_{obj} value at every generation
Repeat above steps for all generations and f_{objopt} among all generations
While end.

3. PROPOSED TECHNIQUE

The approach which is explained in previous segment is united and forms the complete proposed philosophy. The reshape and placement of DGs with hybrid optimization is the proposed methodology for the paper. The reconfiguration is optimized with PSO algorithm and DGs are optimally located with WOA. The segment is sub-divided with demonstrating of DGs and hybrid improvement calculation alongside flow outline appeared in Figure-7.

3.1 Modeling of DG

3.1.1 Modeling of Type-1 DG

Distributed generators are erected in scattering networks that are straightforwardly delivering the produced power to load. Molding of DGs are explained the behavior of the device at the system. Type I DGs are supplying real current to the load which is connected at that bus. Figure-3 clearly reflects DG is providing actual current to load.

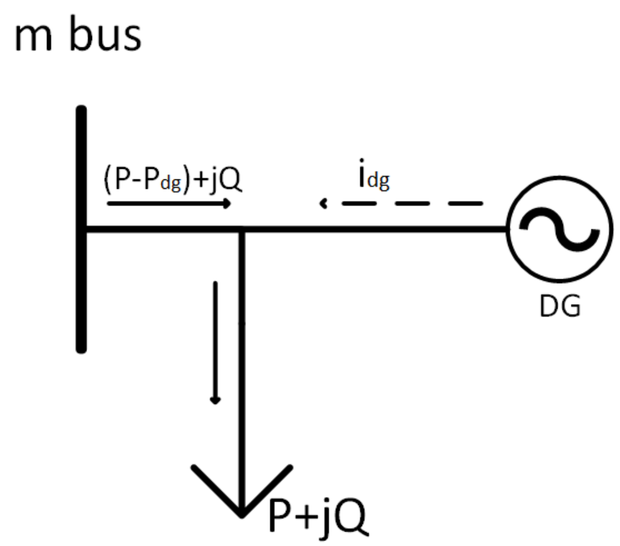

Figure-3. Modeling of Type-1 DG in radial distribution system.

3.1.2 Modeling of Type-2 DG

The modeling of Type-2 DG is just similar to the Tpye-1 DG. In Type-2 DG, reactive power of load is compensated by DG. So, behavior of Type-2 DG is that it injects the required wattles power to the load, which will enhance the voltage profile of the system.

3.2 Proposed Algorithm

The algorithms which are detailed in the prior segment are combined to explain the optimization problem, for reconfiguration of RDS and placement of DG to make best use of the savings in RDS. Load flow algorithm has been used at each optimizing algorithm such as PSO and WOA for reconfiguration and placement of DG. The PSO terms are adopted to RDS for reconfiguration. The dimensions of PSO for tie-line switches in radial distribution system. The particles are populated with dimensions and number of particles. The amount of branches of RDS is always identical to (Nb-Nmf). Where Nb is no. of buses and Nmf is no. of main feeders connected to the grid. Examples of that are IEEE 16 bus system, IEEE 33 bus network and IEEE 69 bus system. IEEE 16 bus system has three feeders which are connected to the main feeders. So, numbers of branches are 13 and number of tie-line switches also three loops are formed with three tie-line switches. IEEE 33 bus system one main feeder connected to the buses so number of arms are 32 and number of tie-line switches are five as five loops are formed with tie-line buttons, 69 bus system one main feeder connected to the buses so amount of branches are 68 and amount of tie-line switches are five as five loops are incorporated with tie-line switches. The reconfigured distribution system is given as input for the WOA, for best possible situation of DG in radial distribution network. The searching agents are initialized with the two dimensions which are placement i.e bus number and size of DG. The least and largest constraints of DG are considered as 10 % and 80 % of system load. The limits for bus location are minimum bus and maximum bus number of radial distribution system.

Table-2 depicts the parameters of PSO and WOA which are used to formulate the algorithm.

Table-2. Algorithm parameters and their values.

PSO		WOA	
No. of particles	**30**	**No. of Searching Agents**	**40**
No. of iterations	50	No. of iterations	50
Max inertia	0.9	-	-
Min inertia	0.2	-	-
Intial velocity	2		-
Final velocity	2	-	-

The objective function which used for this hybrid algorithm is separated for two stages. In first phase, PSO is used to determine the optimal reconfiguration for minimum losses and where as in second stage WOA is used to decide the best possible position of type-1 and type -2 DGs for minimizing loss cost along with installation cost of DGs. So, the objective functions are given as follows

$$f_{objpso} = P_{real(\min)} * K_l (\$/kW) \tag{13}$$

$$f_{objDA} = P_{real(\min)} * K_l (\$/kWh) + \sum_{i=1}^{N_{dg}} DG_i * (K_{dg} (\$/kW) + K_m (\$/kWh)) \tag{14}$$

Where

P_{real} real power losses in kW.

loss cost coefficient k_l is 0.06 \$/kWh.

Setting up cost coefficient k_{dg} is 400 \$/kW.

Maintenance cost coefficient k_m is 0.045 \$/kWh.

4. RESULTS

The performance of the system is identified through two IEEE standard 33 and 69 bus structure. Outcomes of system are explained by means of sufferers and voltage profile system. Voltage report of the structure is determined with reconfiguration and devoid of reconfiguration, DGs and misfortunes are likewise contrasted comparatively without and reconfiguration alongside and devoid of DG. The segment is additionally spllited with IEEE 33 and IEEE 69 bus system.

4.1 IEEE 33 Bus Radial Distribution Network

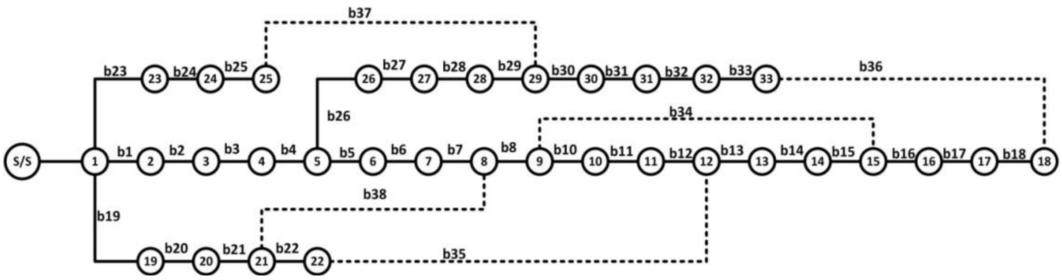

Figure-4. Single line map of IEEE 33 bus RDS.

The single line map of IEEE 33 bus structure is shown in Figure-2. The system has one key feeder and 3 associate feeders. The sub feeders are linked at 2nd bus, 3rd bus and 6th bus respectively. The sub feeder which is connected to 2nd bus are 19, 20, 21 and 22. The buses which are connected to the sub feeder which is connected to bus 3 are 23 24 and 25. The buses which are linked to sub feeder is linked to bus 6 are 26, 27, 28, 29, 30, 31, 32 and 33. The number of loops that are formed with the open switches are five so the number of tie line switches are 33, 34, 35 36 and 37. The losses of the system with only sectionalized switches and all opened tie-line switches are 202.38 kW and the loss cost of the system with 1,06,542.2 USD, with 0.06 USD/kWh. The losses after reconfiguration of 7, 9, 14, 32 and 37 are 139.5 kw and the loss cost of the system with reconfiguration 7, 3321 USD. The reconfigured distribution system is given as input for most favorable position of DG using WOA. The most favorable position of Type-1, Type-2 DG are bath at 28th bus and 29th bus respectively with the sizes of 1118 kW and 1008 kVar respectively, with the reduction of losses to 63.3 kW with loss cost of USD 34,998. The setting up cost of 400 USD/kW. So lastly, the savings of the structure is 38,322 USD /annum with respect to reconfiguration loss cost. The voltage sketch and cost arc for reorganization and DG situation are appeared in the accompanying figures (Figure-5, Figure-6).

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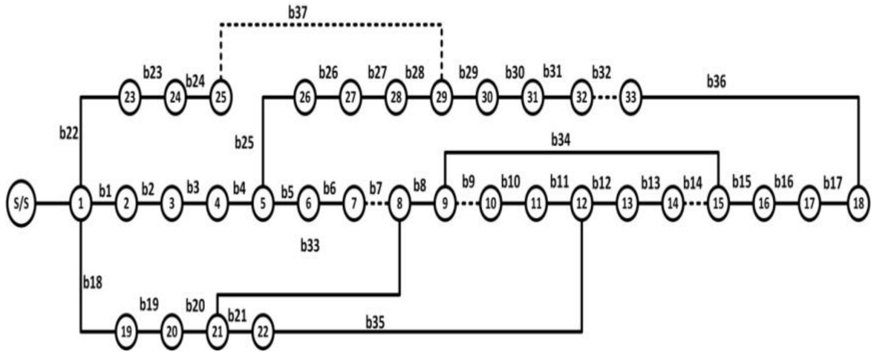

Figure-5. Single line map of 33 bus RDS with reconfiguration.

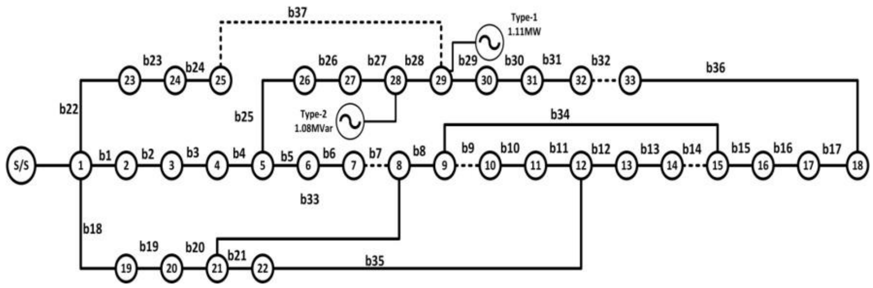

Figure-6. Single line graph of 33 bus RDS with Type-1, Type -2 DG along with reconfiguration.

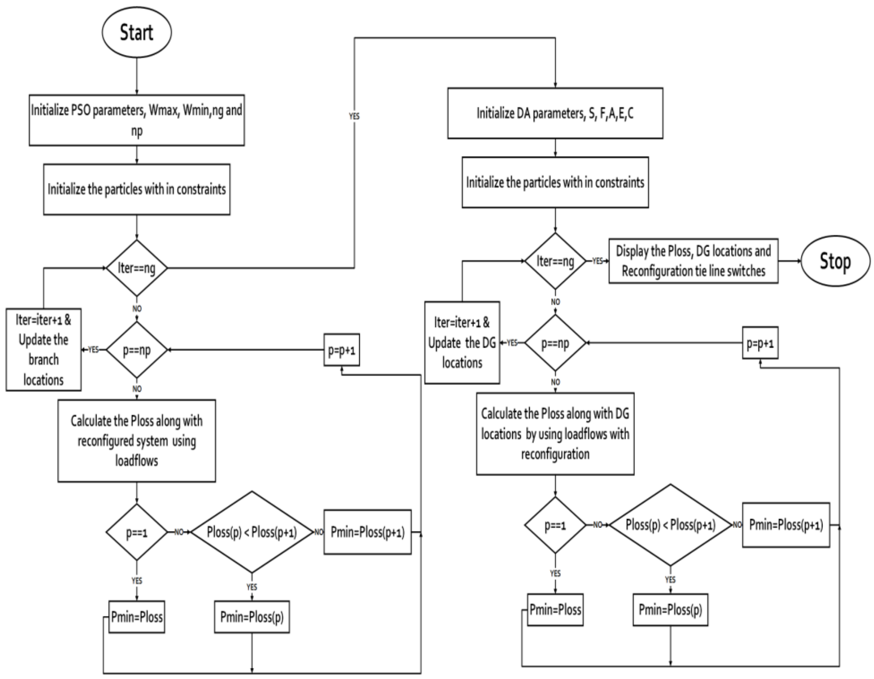

Figure-7. Flow chart for ideal reconfiguration and DG position.

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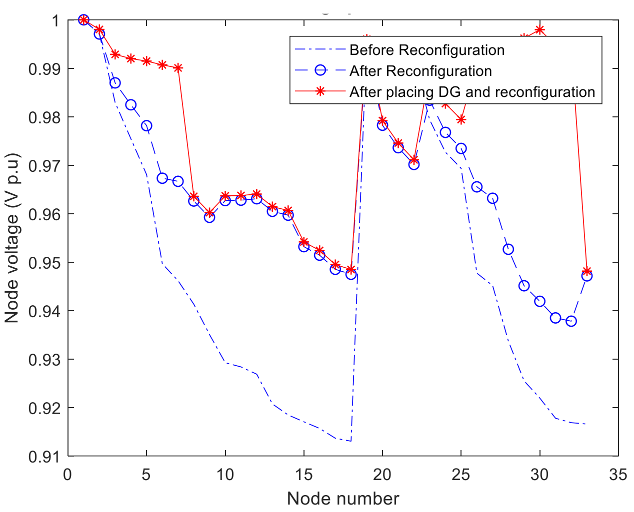

Figure-8. IEEE 33 bus voltage outline with DG, with Reconfiguration and devoid of DG and reconfiguration.

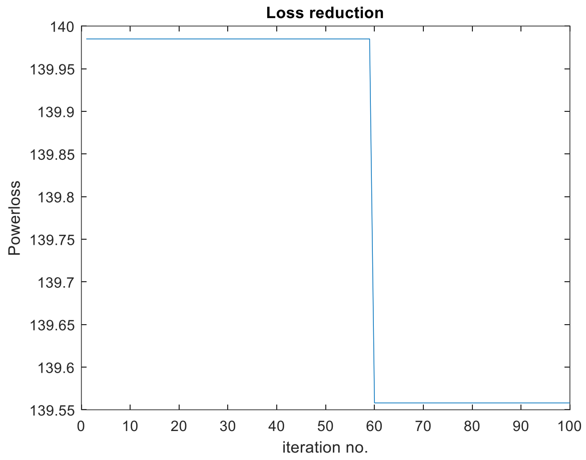

Figure-9. Cost profile of PSO on behalf of optimum reconfiguration.

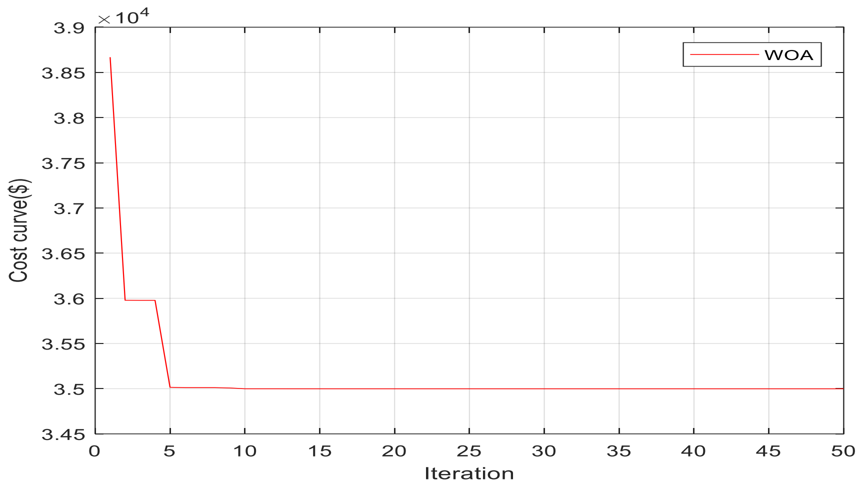

Figure-10. Cost curve of WOA for best possible position of DG.

Table-3. IEEE-33 bus RDS Results with and without DG position along with reconfiguration.

S.No		Base Case	Reconfiguration (devoid of DG)	Reconfiguration (With DG)
1	Switches are open	37,36,35,34&33	37,32,14,7&9	37,32,14,9&7
2	Power loss (KW)	202.38	139.50	63.3
3	% Loss reduction	-	31.07	68.47
4	Lowest voltage (p.u) (Bus No)	0.913(18)	0.9378(32)	0.9478(33)
5	DG Placement (Bus No)	-	-	28(Type -1) 29(Type-2)
6	Type-1 DG Size (kW)	-	-	1118
7	Type-2 DG size (kVar)	-	-	1008
	Loss Cost (USD)	1,06,542.2	73,321	34,998

** Total Loss Cost savings: 38,322 USD/ annum

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4.2 Test Case II: IEEE 69 Bus System

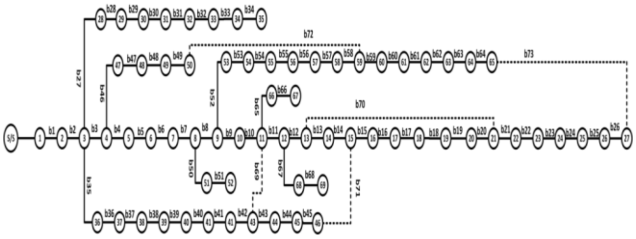

Figure-11. IEEE 69- bus radial distribution system.

The single line graph of IEEE 69 bus RDS is shown in the Fig. There are seven sub feeders which are linked at third bus, fourth bus, eighth bus, ninth bus, eleventh bus and twelfth bus. The important observation for this bus system is two sub feeders are connected to the same bus. Some buses are zero load buses which are used for load balancing in total system for the grid. The number loops formed with tie-line switches (red color) are five. The losses of the system with only sectionalized switches and all opened tie-line switches are 225.38 kW and the loss cost of the system with 1, 18, 261.1 USD, with 0.06 USD/kWh. The losses after reconfiguration of 14, 58, 61, 69 and 70 are 99.5 kW and the loss cost of the system with reconfiguration 52,350 USD. The reconfigured distribution system is given as input for optimal placement of DG using WOA. The optimal position of type-1 DG and type-2 DG are both at 60th and 61st bus with the dimension of 1.14 MW and 1.09 Mvar correspondingly with reduction of losses to 30.37 kW with loss cost of 27,652USD. The setting up cost of 400 USD/kW. So lastly, the savings of the structure 17,736 USD/ annum with respect to reconfiguration of the system. The voltage report and cost arc for reorganization and DG position are shown in subsequent figures.

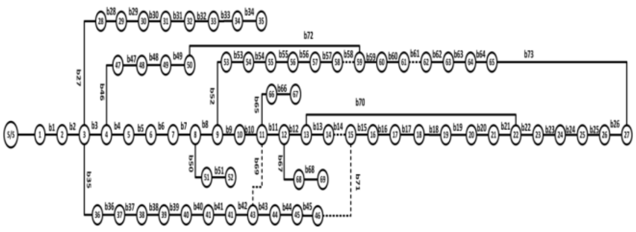

Figure-12. 69- bus RDS with reconfiguration.

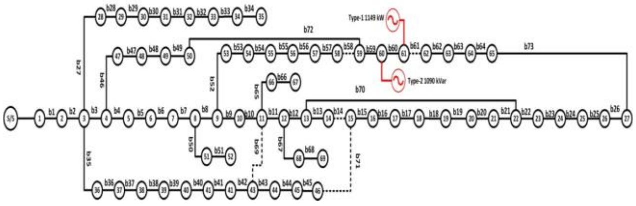

Figure-13. IEEE 69- bus system with Type-1, Type-2 DG.

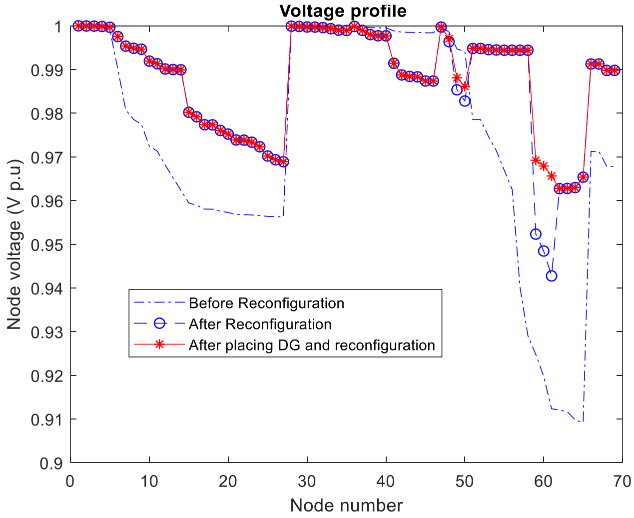

Figure-14. IEEE 69 bus voltage profile with DG, with Reconfiguration and devoid of DG and reconfiguration.

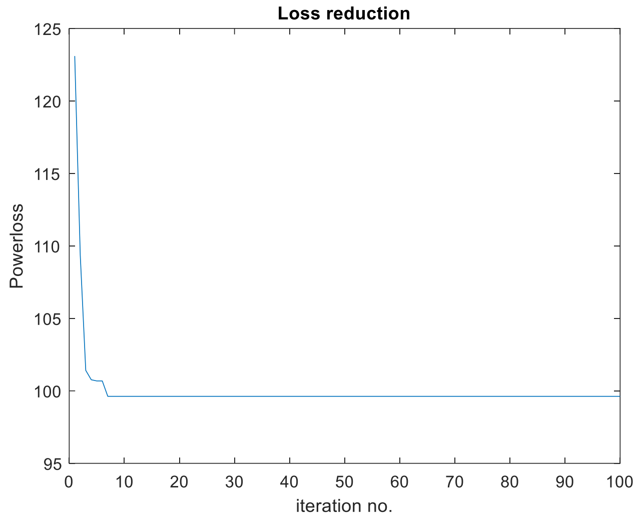

Figure-15. Cost curve of PSO for optimum reconfiguration.

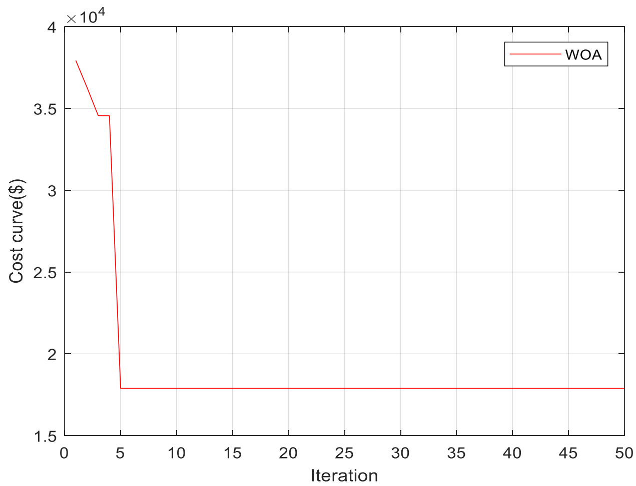

Figure-16. Cost arc of WOA for optimal position of DG.

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Table-4. IEEE-69 bus RDS results with and without DG position.

S. No		Base Case	Reconfiguration (Without DG)	Reconfiguration (With DG)
1	Open switches		14,58,61,69 & 70	14,58,61,69 & 70
2	Power loss (KW)	225.38	99.50	30.37
3	% Loss reduction	-	55.85	86.6
4	Lowest voltage (p.u) (Bus No)	0.9092(65)	0.9428(61)	0.9515(62)
5	DG Placement (Bus No)			60
				61
6	DG Size			1140.9(kW)
				1090.5(kVar)
7	Loss Cost (USD)	1,18,261.1	52,350	17,736

** Total Loss Cost Savings: 34,618 USD/annum.

5. CONCLUSIONS

The paper has dealt with arrangement of type-1, type-2 DG to capitalize on the savings of the framework by including the setting up cost of DG. The paper is utilized PSO for reconfiguration, which is best swarm based calculation for unraveling a wide range of frameworks, and WOA is utilized for ideal situation for type I, type-II DG, which repaid both active and reactive power of the load. The total calculation is appraisal on two experiments which are IEEE 33 and IEEE 69 bus structures. The savings of the frameworks are referenced in USD which is adequately saved per annum.

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