GENETIC ALGORITHM FOR SIMULTANEOUS OPERATION OF OLTC AND DISTRIBUTED ENERGY RESOURCE DEVELOPMENT

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Abstract - *The optimal integration of distributed energy resources (DER) is a mind bogglingly complex optimization problem that traditional optimization methods cannot solve efficiently. This paper solve the problem of DER mix in active distribution network using a genetic algorithm and power flow methods. A new multi objective DER integration problem is formulated to find the optimal sites, sizes while concurrently optimizing the positions of tap of on load tap changing transformer. Considering objectives like losses, DG penetration and voltage profile under different loading conditions. And its impact on voltage stability index .The proposed problem is successfully implemented in matlab on two benchmark distribution network of 33 and 69 buses. Good agreement in matlab/simulink simulation studies and experimental evaluations proves that this method effectively decreases losses and DG penetration, controlling voltage stability parallelly maximizing VSI, in all the techniques of optimal allocation of distributed generation .Consequently reducing the concern over satisfactory and reliable operation.*

Key Words: On load tap changer (OLTC), distributed energy resources (DER), active distribution network (ADN), distributed generation (DG), genetic algorithm(GA),voltage stability index(VSI), shunt capacitor (SC).

1. INTRODUCTION

Distributed generation are defined differently based on the various parameters like voltge level , size of DG, and technology used whether it's a renewable DG ,co-generation,non dispatched etc.[1].According to CIGRE ,the council on large electric systems ,define it as a system that is not centrally planned or dispatched size should be smaller than 50-100MW and connected to the distribution side of the system [2].There are many author that defined DG based on the size of DG connected on the generation end [1].For example micro distributed generation for 1w to 5KW,small distributed generation for 5KW to 5MW, medium distributed generation 5MW to 50MW,and large distributed generation 50MW to 300MW.There are various benefit of using distribution generation for requirement and effectiveness of the supplied electricity . It is necessary to optimally locate and size DG resources. [3] Optimal dg placement can provide with more reliability, minimum voltage deviation and many other benefits as well. Whereas non optimal placement of the DG may decrease reliability and stability of the system.

There are various optimization based methods which has been utilized to place the dg some of them are ant lion optimization algorithm, hybrid particle swarm optimization , the backtracking search optimization algorithm, Stud Krill herd Algorithm, crow search algorithm etc. Various paper on above mentioned algorithm are published considering different techniques of dg placement. Like variables objective, constraints, quantity of DG units, nature of load, planning method etc.[11],[8],[9].This research paper utilizes the conventional genetic algorithm method for DG placement in two different bus system using OLTC method for decreasing losses as well as DG penetration of the system significantly .It also uses OLTC with shunt capacitor to show that it is also compatible with other methods giving similar benefits and better .

2. PROBLEM FORMULATION

In general we have to achieve multiple objectives simultaneously along with the minimization of power losses there are other parameters distribution companies must take into consideration such as voltage regulation ,reliability, power quality ,frequency etc.[6] In this problem ,we take three equivalent parameters to optimize simultaneously, minimizing system losses ,minimizing voltage deviation, maximizing voltage stability index. As voltage deviation alone is not enough we use VSI to check voltage stability.

OBJECTIVE FUNCTION

The following objective function has been formulated

min $F=F_1+F_2+F_3$

Where,

$$F_1 = \sum_{k=1}^{n}\sum_{j=1}^{n} R_{kj}\cos(\delta_k-\delta_j)/V_k V_j\,(Q_k Q_j + P_k P_j) + R_{ij}\sin(\delta_k-\delta_j)/V_k V_j\;\;(Q_k P_j - P_k Q_j) \quad \{1\}$$

$$F_2 = \sum_{j=1}^{n}\;\{\;V_k - V_{rated}\}_2 \quad \{2\}$$

$$F_3 = \frac{1}{\min VSI_{kj}} \quad \{3\}$$

$$VSI_{kj} = V_j^4 - 4(P_k R_{kj} + Q_k X_{kj})V_j^2 - 4(P_k R_{kj} - Q_k X_{kj})^2 \quad \{4\}$$

Here V_k, δ_k =real load demand, voltage magnitude and angle at node i respectively

$$P_k = V_k \sum_{j=1}^{n} V_j . Y_{kj} . \cos(\theta_{kj} + \delta_k - \delta_j) \quad \forall k \quad \{5\}$$

$$Q_k = -V_k \sum_{j=1}^{n} V_j . Y_{kj} . \sin(\theta_{kj} + \delta_k - \delta_j) \quad \forall k \quad \{6\}$$

$$0.95 \le V_k \le 1.05 \quad \forall k \quad \{7\}$$

Here P_k^{DER} =DER capacity assumed to be deployed

$P_{maximum}^{DER}$=maximum allowed DER size at a node

$$0 \le P_k^{DER} \le P_{maximum}^{DER} \quad \forall k \quad \{8\}$$

n_{der}=no. of DERs to be installed in distribution system respectively

$$\sum_{i=1}^{n_{der}} P_k^{DER} \le 1.6 \sum_{i=1}^{n} P_k^d \quad \{9\}$$

Here $I_{kj}, I_{kj}^{maximum}$ = current and maximum current limit

$$0 \le I_{kj} \le I_{kj}^{maximum} \quad \forall k \quad \{10\}$$

Slack bus voltage and angle

V_1 =1.0, $\delta_1 = 0$ {11}

3. GENETIC ALGORITHM

Genetic algorithm is a heuristic search method. The basic idea is very simple firstly a population is generated and then the population is evolved based on the processes analogous to biological processes of selection, mutation and crossover method .In this selection is based on the survival of fittest theory by Charles Darwin , the programming and manipulation of search data is on the basis of genetic DNA. In this paper we utilizes genetic algorithm to find the optimal solution among all the possible solutions .Newton Raphson method is used for finding load flow in the system .The basic idea is as shown in below given chart.

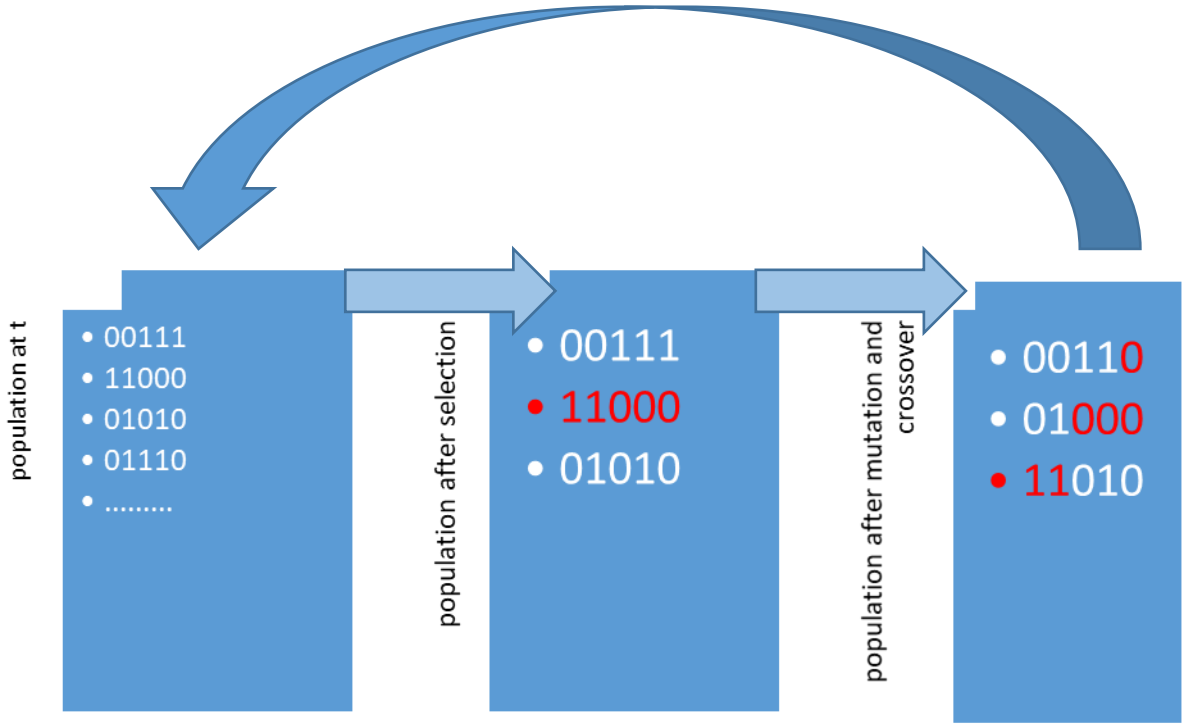


FIGURE 1: Basic mutation,crossover,selection on basic binary numbers.

The above shown diagram shows the way by which selection, crossover and mutation takes place. Here the binary number represent chromosomes and out of n number of chromosomes a few of them get selected based according to fitness value. Selection is implemented by eliminating low fitness genes from the system and also we use inheritance here to increase the value of high fitness function in the system. [7] After that crossover and mutation takes place as shown in figure 00111 get mutated to 00110 and 11000 and 01010 crossover to form new number it generally implies exchange between two individuals. Genetic operators are applied probabilistically and new numbers are formed 01000 and 1101.Genetic algorithm can be used for mathematical modelling and also various problem solving, method use is described in below given chart.

4. CASE STUDY

In this paper matlab simulation result and case studies have been presented. Conventional genetic algorithm is used along with OLTC tap positioning. optimization problem showed in problem formulation section have been solved for two benchmark system 33 bus system and 69 bus system .In practical there are many challenges during optimal integration depending upon various physical parameters may be the availability of space, land, availability, technical ability of the various systems or energy resources in case of renewable system .in this work we assumed nodes to be at equal potential. In this paper it is already assumed that an OLTC tap is already deployed in the system.

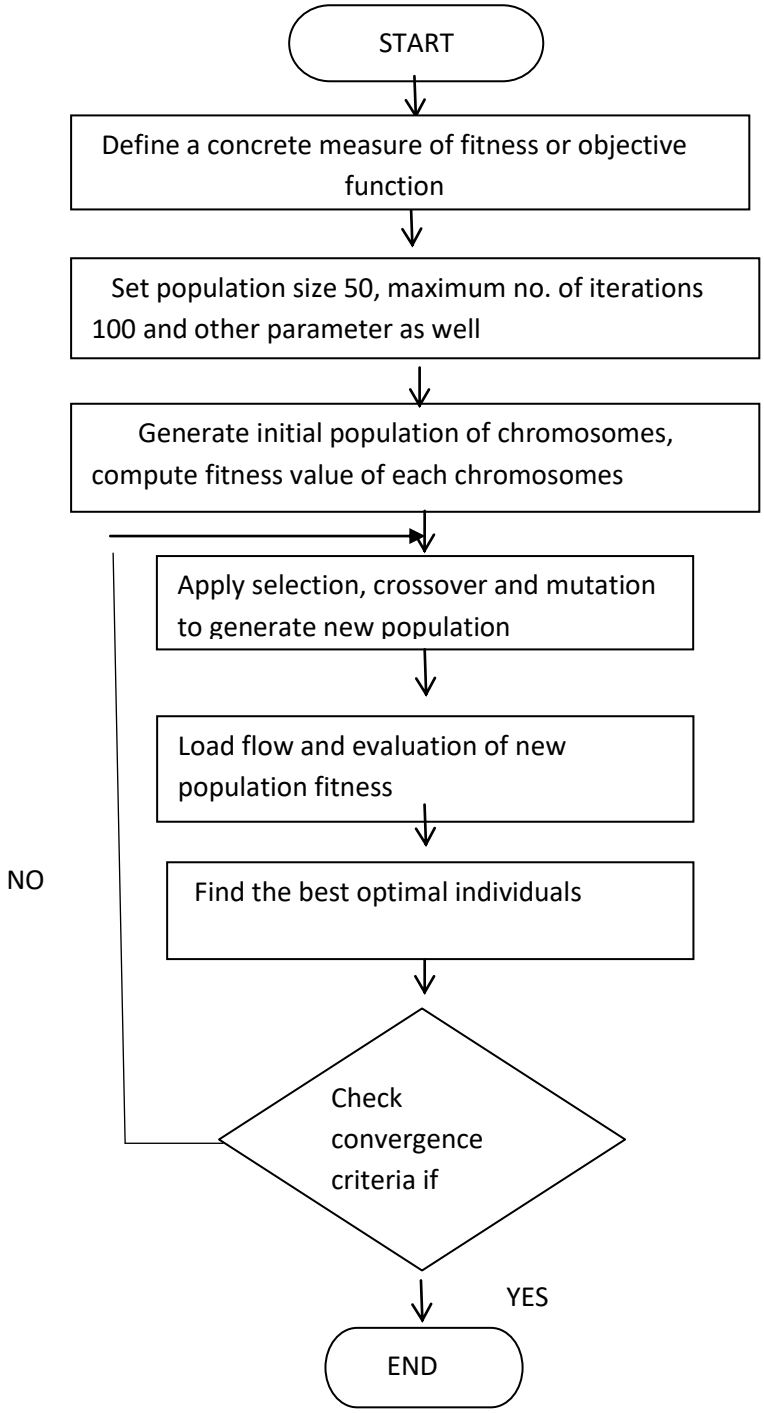


Figure 2: Flow chart of various step followed for optimal allocation.

In order to observe the effectiveness of the system, the following cases has been framed and investigated.

Case 0: Base case (without DG) for peak load, normal load and low load respectively.

Case 1: Optimal integration of DGs using genetic algorithm for peak load, normal load and low load respectively.

Case2: Optimal integration of DGs in conjunction with OLTC for peak load, normal load and low load respectively.

Case3: Optimal integration of DGs in conjunction with OLTC and shunt capacitor for peak load, normal load and low load respectively.

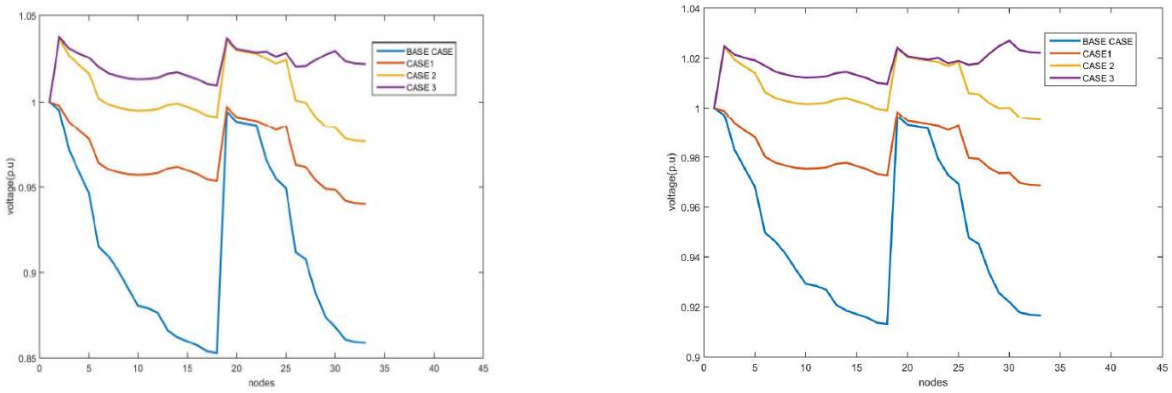
Table 1: Comparison of simulation result obtained by study system 1.

Cases	Optimal DER nodes (sizes in MW)\ Optimal SC(sizes in MVAR)	LOSSES	OLTC TAP	MIN V	MAX V	VSI	DER
BASE CASE	-	0.5753^{P} 0.2027^{N} 0.0471^{L}	-	0.85 0.91 0.96	1 1 1	0.53315 0.6989 0.84626	0
CASE 1	25(1.323),30(1.4899),14(1.277) 25(0.876),30(1.092),14(0.765) 25(0.434),30(0.538),14(0.379)	0.19526^{P} 0.072208^{N} 0.017499^{L}	NA	0.94 0.97 0.98	1 1 1	0.78321 0.8822 0.94063	59.08 39.48 19.51
CASE 2	25(1.323),30(1.3499),14(1.247) 25(0.76419),30(1.0924),14(0.765) 25(0.434),30(0.538),14(0.379)	0.18288^{P} 0.06864^{N} 0.01749^{L}	3 2 0	0.98 0.99 0.98	1.03 1.02 1	0.9126 0.9811 0.94063	56.62 37.87 19.51
CASE 3	14(1.247),25(1.323),30(1.35)\ 30(1.978) 14(0.762),25(0.764),30(1.085)\ 30(1.978) 14(0.376),25(0.434),30(0.534)\30 (1.978)	0.05622^{P} 0.02069^{N} 0.00533^{L}	3 2 0	1 1 0.99	1.03 1.02 1.00	0.968 0.998 0.970	56.62 37.71 19.415

According to the study system results are presented below:

A) Study system 1: It is a 33-bus radial distribution 12.66kv test system, with total real power demand of 3.715 MW and reactive power demand of 2.300 Mvar [4].

Table 1 shows the various cases applied to a 33 bus system to test the robustness of the following system it is solved for low load, peak load and normal load. Given table also shows the impact of using DGs and OLTC on the various other parameter of the system like voltages, voltage stability index and DG penetration of the system. Also case 3 shows that using OLTC as voltage regulator can be helpful along with other voltage regulators such as capacitor bank in this case we deploy a 3MVA of capacitor at a single position by using genetic optimization algorithm. We have taken same position of DG as well as capacitor to make it easy to deploy changing every time the position of variable controllers are not possible. Figure 1 shows the variation of voltages at various nodes during normal load period and peak load period for cases stated above. In this case we deploy DGs at three nodes 14, 25, 30, these point are obtained by simulation result using genetic algorithm.



(A) (B)

Figure 3: Shows the graph for (A) peak load system and (B) normal load system under all three cases for 33 bus system.

B) Study system 2: The proposed multi objective DG allocation problem is also solved for 69-bus radial test distribution system [5].It is a 12.66 KV network with load demand of 3.80MW and 2.690MVAR..In this case we deploy DGs at three nodes 60,62,27 and capacitor at 61 node as shown in table for various cases .These point are obtained by simulation result using genetic algorithm .

It has been observed that the proposed point provide the most optimal solution for all kind of loads may be the value of DER penetration is slightly higher but it gives best solution in all three cases of load and reducing losses of the system. The table contains optimal DER nodes and capacities along with the values of various objective function like loses, voltage stability index, min and max voltage. Graph below shows the competitive analysis of various cases according to the voltage in various cases.

C) Performance analysis of proposed system: In this section we compare the performance of the system with and without OLTC tap. As seen from the table and various figures we can clearly state that performance of the system in base case condition the system show poor node voltage variation during peak and nominal load levels. The optimal allocation of DGs is achieved in Case 1 which improved the node voltage profile along with reducing the losses .in case 2 optimal allocation of DGs along with OLTC tap has reduces the losses significantly along with stabilizing the voltage and decreasing the DER penetration of the system in comparison to previous case .case 3 clearly shows that OLTC is easily compatible with capacitor placement and shows better result .In overall consideration ,there is significant decrease in losses of the system along with maintaining the voltage within the desired limit and improving voltage stability index .The proposed model also reduces the problem of coordination as it take into consideration existing VRs while implementing new DERs .

Table 2: Simulation result obtained by study system 2.

Cases	Optimal DER nodes (sizes in MW)\ Optimal SC(sizes in MVAR)	LOSSES	OLTC TAP	MIN V	MAX V	VSI	DER
Base case	-	0.5605 P 0.2247 N 0.0515 L	-	0.85 0.91 0.96	1 1 1	0.5407 0.6869 0.8405	0 0 0
CASE 1	60(1.492),62(1.4989),27(0.644) 60(0.482),62(1.351),27(0.397) 60(0.242),62(0.66),27(0.196)	0.1978 P 0.07455 N 0.01826 L	NA	0.96 0.98 0.99	1 1 1.00	0.87048 0.92322 0.9609	48.87 29.973 14.758
CASE 2	60(1.2801),62(1.499),27(0.622)	0.18367 P	3	0.99	1.03	0.991	45.712

	60(0.437),62(1.351),27(0.356) 60(0.242),62(0.66),27(0.196)	0.07088 N 0.01826 L	2 0	1.00 0.99	1.02 1.00	0.989 0.9609	28.817 14.758
CASE 3	60(1.28),62(1.499),27(0.621)\ 61(2.083) 60(0.436),62(1.351),27(0.356)\ 61(1.299) 60(0.23),62(0.66),27(0.195)\ 61(0.649)	0.03746 P 0.01420 N 0.00368 L	3 2 0	1 1 0.99	1.03 1.02 1.00	0.998 0.989 0.979	56.62 37.71 14.583

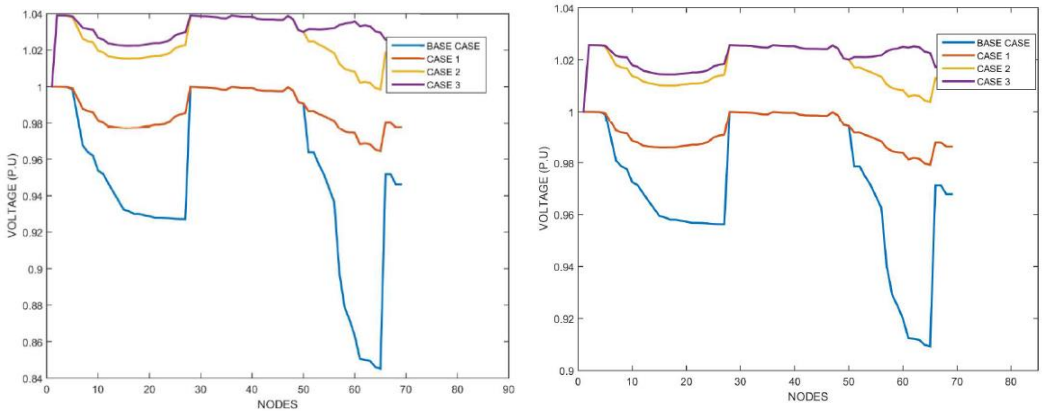


FIGURE 4: Shows the voltage corresponding to each node for peak and normal load for 69 bus system.

5. CONCLUSION

In this paper ,we discusses the various benefits of using one of the existing voltage regulators method oltc for DGs placement in active distribution network and its benefits and impact on various other parameter like VSI and DG penetration. Result of Simulation obtain from 33 bus system and 69 bus system in this surely provide better options to engineers for successful implementation of active distribution network. Comparison of conventional results from system and new results show improvements that can be made by using such methods. We believe that the proposed method is highly applicable to solve the various distribution system.

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