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Optimal Action of Soft Open Points in Distribution Systems Based on Single and Multiple Objective Particle Swarm Optimization: A Comparative Approach

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Abstract

Distribution networks of electrical power are becoming increasingly active through integration of small generating units. However, the topology of the distribution network may hinder large scale integration of those generating units thereby decreasing the benefits of an active distribution network. Soft open points (SOPs) are considered one of the solutions to alleviate the hampering of integration of local sources by altering the topology of the distributed network.

In this paper, the problem of finding the optimal operating points of SOPs are analyzed and investigated. Two approaches are adopted; by using single objective particle swarm optimization (PSO) and multiple objective (MOPSO). In the former, a set of objectives are optimized on a one by one bases whereas in the second method, the set of objectives are optimized together at the same time. The set of objectives are the typical, active power loss, voltage profile and feeder load balancing. A comparative approach is adopted in this paper with the intention of finding the best approach that yield optimum points. Optimum points which are defined as a set of active/reactive powers for each converter of the SOP. These optimum points are further employed by designers as reference settings for the control system which governs the local operation of the SOP system.

Results from simulations carried out on the IEEE 33 bus system with and without multi capacity local energy sources, shows that the three objectives are better optimized using PSO than MOPSO keeping in mind that the PSO requires less computation effort compared to MOPSO. Moreover, better PSO performance is observed as the amount of power injected by a distributed source (DG) increases. The former is also true when the system is optimized by MOPSO.

Keywords: Soft Open Points, distributed generators, single optimization method, multi-objective optimization method, back-to-back power converters, power electronic devices.

1. Introduction

Extensive use of distributed power resources leads to multiple problems including: increased power loss ,voltage deviation and load imbalance. The topology of the distribution network may significantly contribute to these problems. In distribution networks, there are usually open points between adjacent feeders. These open points (switches) are usually closed, while other switches are open to achieve proper load distribution between the feeders. Previous researches has been done on network reconfiguration in order to achieve optimal network operation (reduce power loss, optimize voltage profiles and achieve load balancing), but this method is very limited in use due to the high cost of remote controlled switches and maintenance of devices [1-3]. Recently, a method to improve network operation without resorting to the network reconfiguration is the use of power electronic converters called soft open points (SOP) [4-8]. These devices have been adopted to improve network operation due to its ability to flexibly control the flow of active power in addition to some of the advantages it possesses compared to reconfiguration of the network [7]. SOPs can be used to connect any collection of feeders, for example, supplied from dissimilar substations with different levels of nominal voltages resulting in many benefits [8].

Work presented in [4], investigated the ability of SOP in mitigating overload conditions. Only one objective was considered in the analysis. Authors employed Powell's direct set (PDS) as the optimization tool to find the optimal operating points. The gains of using SOPs in the medium voltage distribution network for three objectives, feeder load balancing, power losses minimization and voltage profile improvement tested in IEEE 33bus using Powell's direct set method (PDS) is presented in [5]. Authors in [6] presented a multi-objective PSO integrated by the taxi cab method. In this work, the elements in a limited size archive stores the non-dominated solutions that represent the optimal operating points of an SOP. These points were further refined through an employment of a local search method. The results were obtained for only one location of a tie line for the IEEE69 bus system.

To determine the KW and KVAR power operating settings for an SOP on an 11 kV network, a non-linear programming optimization was devised in [7]. The SOP's operational zone was determined within its voltage-limit boundaries using a Jacobean matrix-based sensitivity analysis, and it was then graphically shown for various demand and generation situations at the feeders for both terminals of the SOP. Three optimization objectives: reducing energy loss, improving the voltage profile and balancing line utilization were used to pinpoint the precise operating point.

In this work, two optimization approaches are investigated. The first is optimizing the SOP operating point based on a single objective PSO, in which optimizing of an objective function is carried out one at a time. The second is based on a multi-objective PSO which optimizes all targeted objectives at the same time. The main emphasis of the present work is to provide a simple platform for obtaining the operating points of the SOP at different locations of the tested distribution network. The accuracy and simplicity of the optimization method will play a crucial role in providing reference settings for the converter control of an SOP system. Each approach is tested under a variant amount of DG capacity.

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2. Model of Soft Open Point in Distribution Networks

In distribution system, the classical topologies are either radial or ring type. The common radial structure has number of bus bars that are equal to one plus the number of nodes in the system. Some radial feeders have nodes that are normally open point (NOP) [9]. The idea of SOP is to connect any two NOPs together using two power electronics converters, operated as back-to-back with a middle DC link port [10]. Depending on the power flow, one converter is operated as an AC/DC converter whereas the other operates as DC/AC. Figure 1.a shows a typical two feeder distribution system and Fig. 1b shows an SOP which is connected between bus bars x & y.

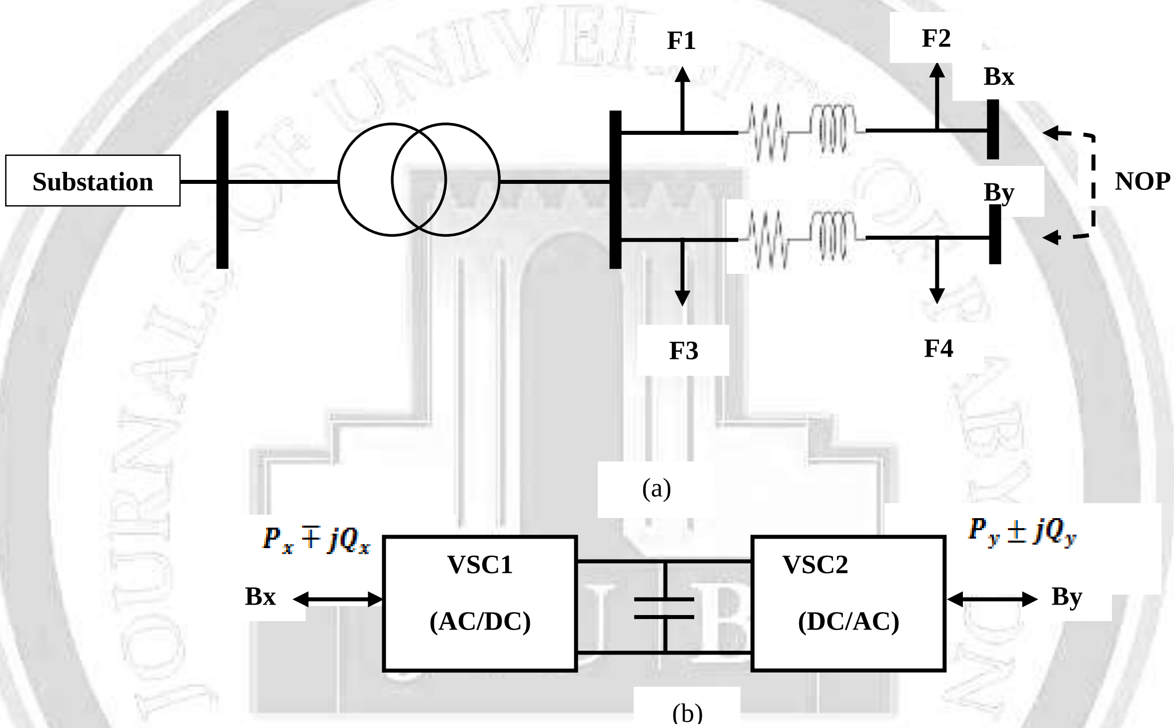

Fig.1. Schematic of, (a) simple two feeder distribution system and (b) SOP.

To completely judge the potential merits during non-transient operation of the network, the SOP device is usually modelled as an injection or supply of active/reactive power [11]. In power analysis of distribution networks, usual procedure is to find the power flow injected into a bus based on the flow from the previous bus. Referring to fig.2, the power equation at bus $i+1$ is given by [12],

$$P^{i+1} = P^{i} - Pl^{i+1} - Ploss^{(i,i+1)} \quad (1)$$

$$Q^{i+1} = Q^{i} - Ql^{i+1} - Qloss^{(i,i+1)} \quad (2)$$

where P^i and Q^i are the real and reactive powers flowing out of bus i, while P^{i+1} and Q^{i+1} are the real and reactive powers flowing into bus $i+1$, pl^{i+1} and Ql^{i+1} are the real and reactive load powers at bus $i+1$, and $Ploss^{(i,i+1)}$ / $Qloss^{(i,i+1)}$ are the real/reactive power losses of the line section linking buses i and $i+1$. The losses in the connection of buses i and $i+1$ are calculated as [13],

$$Ploss^{(i,i+1)} = R^{(i,i+1)} \times \frac{P^{i2}+Q^{i2}}{|V^{i2}|} \tag{3}$$

$$Qloss^{(i,i+1)} = X^{(i,i+1)} \times \frac{P^{i2}+Q^{i2}}{|V^{i2}|} \tag{4}$$

Based on Eq. (3) & (4), (1) & (2) can be rewritten as,

$$P^{i+1} = P^{i} - Pl^{i+1} - R^{(i,i+1)} \times \frac{P^{i2}+Q^{i2}}{|V^{i2}|} \tag{5}$$

$$Q^{i+1} = Q^{i} - Ql^{i+1} - X^{(i,i+1)} \times \frac{P^{i2}+Q^{i2}}{|V^{i2}|} \tag{6}$$

The voltage profile at bus $i+1$ can be expressed interms of voltage at bus i as [13],

$$\left|V^{(i+1)^2}\right| = \left|V^{i^2}\right| - 2\left(R^{(i,i+1)}p^{i} + X^{(i,i+1)} * Q^{i}\right) + \left(r^{(i,i+1)^2} + x^{(i,i+1)^2}\right) \times \frac{P^{i2}+Q^{i2}}{|V^{i2}|} \tag{7}$$

V^{i} ,V^{i+1} in eq.(7) are the voltages at bus i & $i+1$ respectively. The ohmic resistance and reactance of the line section between buses i & $i+1$ are indicated by $R^{(i,i+1)}$, $X^{(i,i+1)}$ respectively

As far as the SOP operation is concerned, the active power exchange between the converters must sum up to zeros [7], whereas reactive power flow remains dependent on the exchange at each AC side. Hence, assuming a lossless converter and neglecting the losses in the interfacing filter, the active power exchange is denoted as,

$$P_{c1} = P_{p} \tag{8}$$

$$P_{c2} = P_{q} \tag{9}$$

Where the active power flows for each converter of the SOP are denoted by P_{c1} and P_{c2}. Hence the sum of power exchange between buses p &q is given as,

$$P_{c1} + P_{c2} = 0 \tag{10}$$

From Eq.(10), the relationship between either ends of the SOP system is given as,

$$P_{c1} = -P_{c2} \tag{11}$$

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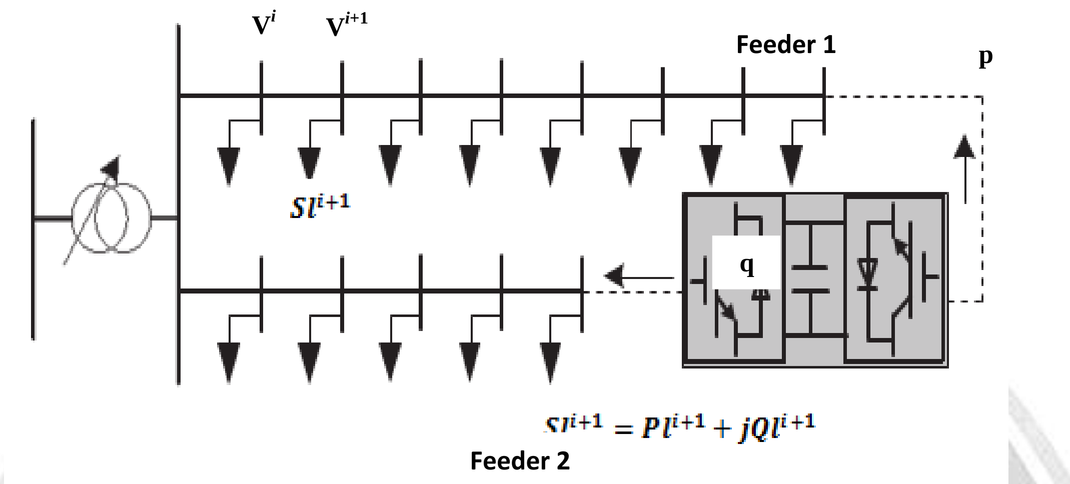

Fig.2. Network with an SOP at terminals p & q buses [7]

2.1 Constraints

The two VSCs' active power exchange and the voltage are restricted by [7],

$$\sqrt{P_{c1}^2 + Q_{C1}^2} \leq S_{rated\,1} \quad (12)$$

$$\sqrt{P_{c2}^2 + Q_{C2}^2} \leq S_{rated\,2} \quad (13)$$

$$V_{minp} \leq |V_{vsc1}| \leq V_{maxp} \quad (14)$$

$$V_{minq} \leq |V_{vsc1}| \leq V_{maxq} \quad (15)$$

Where Q_{C1} and Q_{C2} are the reactive power injections of each converter of the SOP . $S_{rated\,1}$, $S_{rated\,2}$ are the nominal power of each VSC . V_{min} and V_{max} are the minimum and maximum permitted voltages at buses to which the SOP is connected.

3.Optimization Formulation

Investigations were conducted into the advantages of SOPs for system ohmic losses, voltage profile improvement and load balancing of a branch in the grid. Usual procedures involves finding a solution to a set of combined nonlinear optimization problem subjected to some enforced limits or constraints. Then the amounts of actual and reactive power injections of an SOP can be calculated in order to quantify these advantages.

In this work, the improvements brought by SOP is initially calculated using the single objective particle swarm optimization (PSO) technique using each of the three objective functions separately. Then, to estimate the SOP improvement, we employ multi-objective particle swarm optimization method (MOPSO) that considers all three objective functions simultaneously.

Vol. 32, No. 1. \ 2024 ISSN: 2616 - 9916

3.1 Objective Functions

The objectives of power loss reduction, improving the voltage profile and balancing the load, are targeted to reach the best values of those functions. Apart from the load balancing factor, the other two objectives are targeted for minimization. The following mathematical expressions describe each objective:

Obj1: power loss reduction (P loss), which is formulated as,

$$\mathrm{Obj1} = \sum_{i=1}^{Nbranch}(P^{i} - P^{i+1}) \tag{16}$$

Where P^{i} is active power from bus i , P^{i+1} is the active power to bus $i+1$, $Nbranch$ is the total number of branches.

Obj2: voltage profile (VP), which is given by,

$$\mathrm{Obj2} = \sum_{k=1}^{Nbus} |(V_k - V_{k\_ref})| \tag{17}$$

where V_k is the voltage per bus-bar in the analyzed distribution network, 1 p.u. was taken as V_{k_ref} for all bus-bars.

obj3: load balance index (LBI), which is given by,

$$\mathrm{Obj3} = \sum_{i=1}^{\mathrm{Nbranch}} \frac{\mathrm{I}_{\mathrm{flow}\_i}}{\mathrm{I}_{\mathrm{rated}\_i}} \tag{18}$$

where $\mathrm{I}_{\mathrm{flow}\_i}$ is the current flow in the branch connecting the bus i to the next bus which is $i+1$, $\mathrm{I}_{\mathrm{rated}\_i}$ is the rated current of branch i, In this study the feeders of the tested distribution network are divided into two halves, the first half indicates that a current carrying capability, for branches (1-9), to be 400 A. While the second half indicates that the current carrying capability, for branches (10-32), is 200 A [14].

3.2 Optimization Algorithm Technique

3.2.1. Single objective Particle Swarm Optimization (PSO): PSO algorithm's performance in providing an optimized objective has encouraged researchers to apply this biologically inspired method to other domains.

The PSO algorithm was first put forth by James Kennedy and Russell C. Eberhart [16]. PSO is a population-based search algorithm that mimics the social behavior of flocks of birds. Although PSO was initially used to balance the weights in neural networks, it quickly gained popularity as a global optimizer, especially for issues where the decision variables are real values . In order to establish common terms for this algorithm, there are some definitions of many of the most commonly used technical terms, which are detailed in [15]. Based on the details of the algorithm as outlined in [15], particles are "flown" through a hyper dimensional search space in PSO. Based on the social-psychological propensity of people to copy others' success, changes to the position of the particles inside the search space are made. A population of randomly chosen search sites known as particles is used to begin the search. A location vector (x) with M dimensions of information is used to represent each particle; M is the number of choice variables.

Based on [16], in subsequent repetitions, the location vector (x) is continuously modified using a particle velocity. The velocity (v) of a particle is changed at every iteration using the two best values. The first is the position that each particle has individually or personally earned ($pbesti$). The other is the global best position ($gbesti$) attained by any population particle, which serves as a roadmap directing the population to its finest location. The i^{th} particle's velocity and position update equations are [17] ,

$$xi(t) = xi(t-1) + vi(t) \tag{19}$$

$$vi(t) = W\,vi(t-1) + C1r1(pbesti - xi(t)) + C2r2(gbesti - xi(t)) \tag{20}$$

Where W is the inertia weight that regulates how a particle's previous velocity affects its current velocity, or how likely a particle is to keep moving in the same direction. The cognitive learning factor $C1$ symbolizes a particle's desire to its finest work [15]. The social learning factor $C2$, represents a particle's attraction to the best of its neighbors here positive constants are typically used to define $C1$ and $C2$ [15]

Two random values [0,1] called $r1$ and $r2$ are utilized to avoid being confined by a local optimum and to allow for a diversity of particles in the search space [18].

3.2.2 . Multi-Objective Particle Swarm Optimization

To reflect the nature of multi_objective issues, where there are multiple objective functions to be optimized instead of just one, the single objective formulation is expanded [15]. As a result, there are multiple solutions rather than just one. Using Pareto Optimality Theory [19], this set of solutions can discovered. Given that PSO is population-based, it is preferable to generate multiple (different) non-dominated solutions in a single run. Therefore, while extending PSO to Multi-objective optimization, the three essential difficulties to be taken into account, as with any other evolutionary algorithm, [19],

1. What particles should be chosen to act as leaders in order to favor non-dominated solutions over dominated ones?
2. How many non-dominated solutions discovered during the search process are retained such that they can be reported as non-dominated solutions across all previous populations, not just the present one? It is also ideal if these solutions are evenly distributed throughout the Pareto front.
3. How can the swarm's diversity be preserved to prevent convergence to a single solution?

In Multi-objective optimization issues, every particle may have a variety of leaders, but only one can be chosen.

Such a group of leaders is typically kept apart from the swarm in what is called an external archive [15]. The non-dominated solutions that have been discovered so far are kept in this repository (A) [15]. When it is time to update the positions of the swarm's particles, the solutions found in the exterior repository are used as leaders. Additionally, the external archive's contents

Vol. 32, No. 1. \ 2024 ISSN: 2616 - 9916

are frequently given as the algorithm's termination output. According to [15], the initialization of the locations and velocities of the N particles is random, and A is empty at the beginning of the optimization. The beginning location is initialized as each particle's personal bests, then for each iteration updates to each particle's velocities v and locations x are implemented in accordance with eq. (19) and (20). The particle positions after updating might not be within the range of workable solutions.

In this situation, it must be confined to the viable region. Solutions might also be considered based on a given set of constraints. In order to make sure that repository (A) is a non-dominating set, the set out objectives can be assessed with the vector of particle positions in the feasible region . Solutions that are not weakly dominated by any member of the archive are then added to A , and any components of repository (A) that are dominated by x are then removed from A.

4. Simulation and Results of Distribution System

The IEEE 33 bus distribution network is used as a case study to illustrate effectiveness of SOP to reduce power losses, improve voltage profile, load balancing using PSO and MOPSO algorithms. Both algorithms are implemented in MATLAB . Figures (3 & 4) show the flow chart of the PSO and MOPSO studied in this work. All load flow analysis is carried out using MATPOWER 7.0 software [20]. This distribution network has a substation with 37 lines, where 32 of these lines are normally closed switches while five other are normally open switches with a nominal voltage of 12.66 kV [21]. The total P and Q power consumption is 3715 KW and 2300 KVAR respectively. Five normally-open switches (the switches between buses 25 - 29, 33 - 18, 8 - 21, 12 – 22 and 9 - 15) are chosen as nominees venue for SOP connection in this study. Figure (5) shows the IEEE 33 system with locations of SOP connections. In this study both PSO and MOPSO are used to optimize the distribution network via different locations of the SOP system. Table (1) shows parameter used in the simulations carried out in this study.

Table (1). Parameters of SOP system used in simulation

VSC apparent power, $S_{rated\,1}$ & $S_{rated\,2}$	3 MVA
Nominal voltage	12.66 KV
Number of populations	40
Number of particles	4
Size of repository	20 (for MOPSO)
Number of iterations	60
C1, C2	(1, 2) [17]
r1,r2	(0-1) , (0-1) [18]

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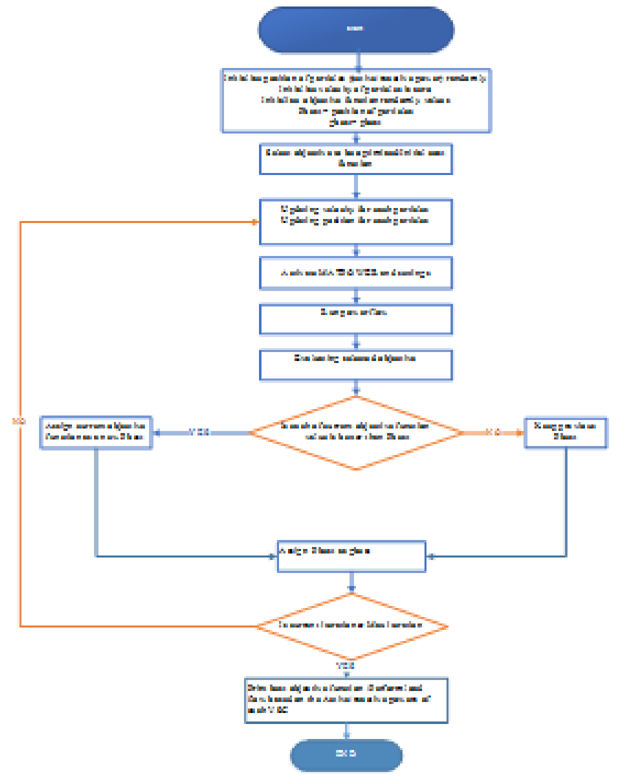

Fig.3. Flow chart of PSO

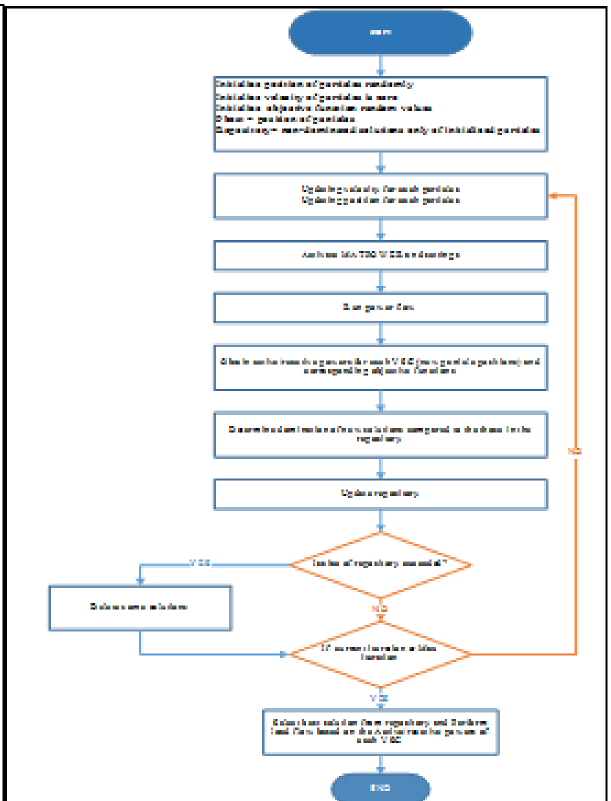

Fig.4. Flow chart of MOPSO

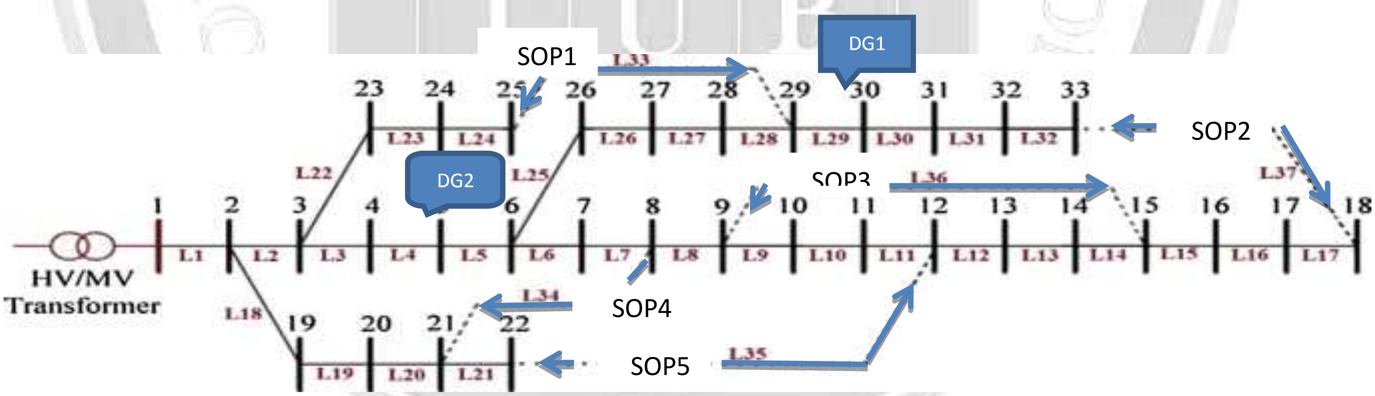

Fig. 5. IEEE 33bus distribution network with SOP and

4.1. Simulation Results for Base Case

In this case the SOP at any location is deactivated and the load flow is run only to find ohmic power losses, voltage profile and load balance factor. Results show that the active loss is is 208.459 kw, voltage profile index (VPI) is 1.6765 p.u with a smallest voltage of 0.91075 P.u, recorded at bus 18 and the load balance index (LBI) is 4.5646. All the simulation cases presented in this work will be compared against values of the base case. In this simulation case, lines connecting buses 25 - 29, 33 - 18, 8 - 21, 12 – 22 and 9 – 15 are left open circuited.

4.2 Optimization of Soft Open Points System using Single Particle Swarm Optimization

The effects of various SOP installation on the three objective functions (power loss minimization ,voltage profile improvement and feeder load balancing) are examined. In this case, the VSC internal losses (switching devices and interfacing filter resistance) are neglected. Applying single objective particle swarm optimization algorithm (PSO) that considers each objective function separately, Table (2) below illustrate results of objective function for each location of SOP in the network.

Table (2) Results of three objective using PSO/optimized separately

SOP Location	Objective(1): minimization of active power losses			Objective(2):Voltage profile improvement			Objective(3):Load balance indexing		
	P loss	VPI	LBI	P loss	VPI	LBI	P loss	VPI	LBI
8-21	123.355	0.950	3.846	187.421	0.526	6.091	138.884	1.211	3.620
9- 15	165.833	1.241	3.852	278.408	0.995	6.908	169.945	1.326	3.707
12-22	128.478	0.907	4.464	147.673	0.638	4.901	137.173	1.140	3.745
25-29	131.591	1.200	3.169	226.455	0.854	6.929	134.503	1.321	2.966
18-33	149.341	1.319	3.665	229.371	1.069	7.056	158.936	1.414	3.363

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Vol. 32, No. 1. \ 2024 ISSN: 2616 - 9916

4.3 Optimization of Soft Open Points System using Multiple Objective Particle Swarm Optimization

In this section of the simulation the SOP active/reactive powers are found through optimization of the three objectives that are of vital importance in the distribution system operation. Here a combination of Pareto optimal solutions for the SOP operational points without DG penetration were obtained, which represent the Pareto frontiers [22]. MOPSO algorithm [23] ,which is augmented with MATPOWER functions and load data is used to find the Pareto frontier extreme points on each axis. This shows the best values that can be found for each objective function for all candidate places of SOP which is shown in Fig.6 below. The MOPSO method's results for these extreme points are reported in Table (3) below. Here, it is seen that solutions obtained vary according to the location of the SOP. Some locations such as, (8-21) revels good active power loss decrease and significant voltage profile enhancement but no significant impact of the load balancing factor. The second best location that impacts the power loss and voltage profile is seen at (12-22) but again no that significant impact on the feeder balance profile.

Table(3) results of three objective function using MOPSO

SOP Location	(P loss kw, VPI, LBI)
8-21	(124.815, 0.527, 3.622)
9- 15	(166.97, 0.999, 3.731)
12-22	(128.763, 0.640, 3.757)
25-29	(132.814, 0.858, 2.97)
18-33	(150.412, 1.073, 3.439)

From the results illustrated in Tables (2) and (3) it is noted that the objective functions values of the SOP using single objective particle swarm optimization method (PSO) is better and more accurate than those obtained by using multi-objective particle swarm optimization (MOPSO).

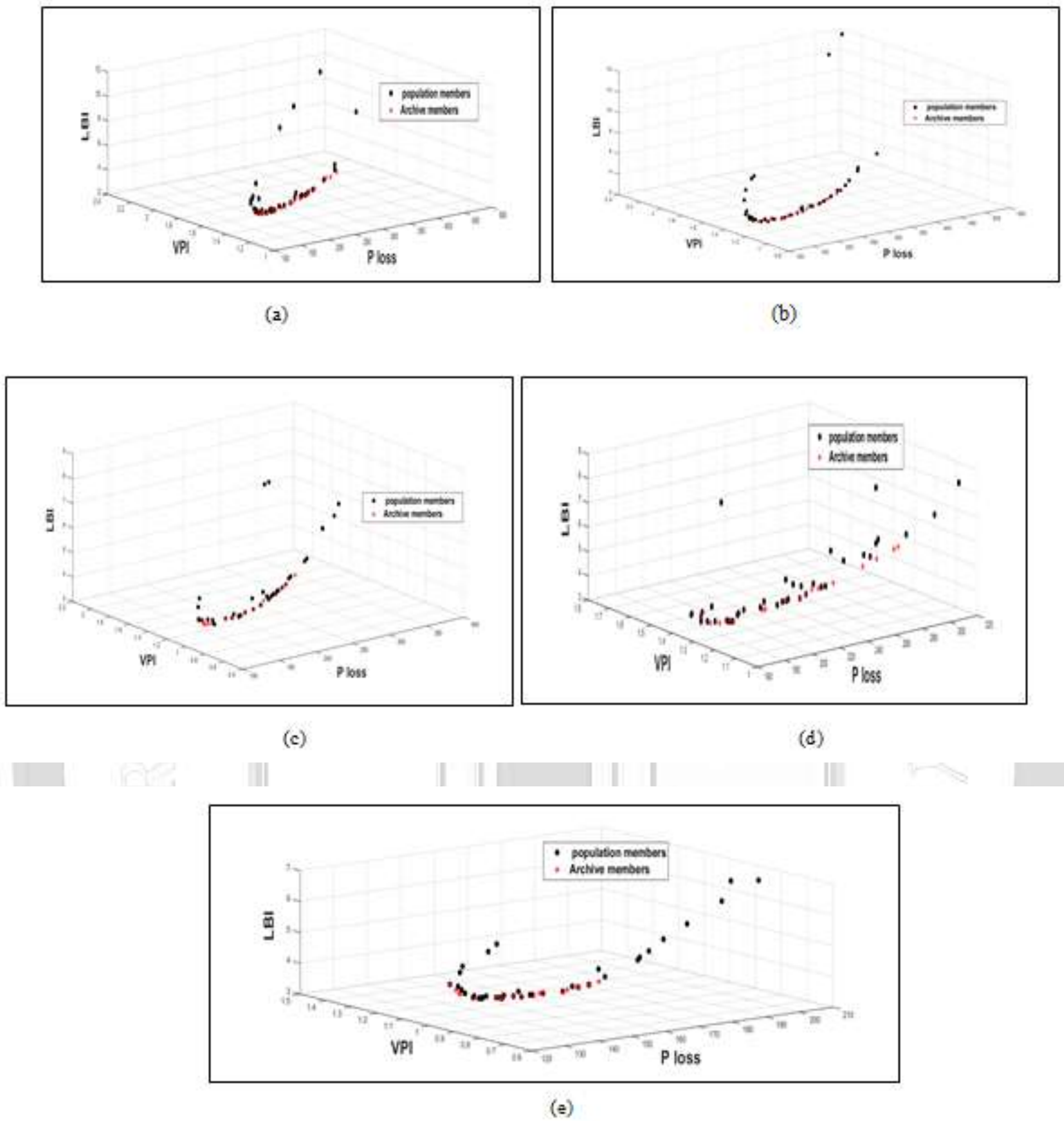

Fig.6. Set of pareto optimal solutions (non-dominated) for each objective function at, (a) SOP at bus 18-33, (b) SOP at bus 25-29,(c) SOP at bus 8-21, (d) SOP at bus 9-15 and (e) SOP at bus 12-22.

4.4 Optimization of Soft Open Points System using Single and Multiple Objective Particle Swarm Optimization with Variable Capacity Distributed Generation Penetration

In this case two DGs are penetrated into the distribution system with a variable capacity. The objective is to first study the performance of the distribution system with SOP interconnection with these DGs. The second is to compare the performance of single PSO and MOPSO in this case. The capacity of the DG is measured as a percentage of the total active power load measured without any overload on the feeders [24]. The DG is considered as a type 1, injecting active power into the bus to which it's connected [25]. In this work, the total power delivered by these sources is divided between the two DGs equally. For this case, a bundle of non-dominated solutions were obtained for each penetration using MOPSO method after modifying the electrical grid data to reflect the injected DG power. Table 4 shows the results of the MOPSO for a DG power ranging from 10%-50%. Figure 7 shows a graphical interpretation of the obtained results. The voltage profile index, load balance index, and network power loss all show a very significant decline. To show the usefulness of MOPSO, the results were compared with PSO in which the algorithm was also modified to reflect DG interconnection. Here, each objective function was optimized separately. Results for this case are shown in Table 5 and Fig.8 Clearly both methods show effectiveness in improving the system performance and producing a well optimized distribution system. Moreover, as the percentage power of DG increase, both methods produce nearly same optimization effectiveness.

Table(4) set of non-dominated solutions by using MOPSO method with DG penetration(10%-50%)

%DG	Sop (8-21)			SOP (9-15)			Sop (12-22)			Sop (25-29)			Sop (18-33)		
	Ploss	VPI	LBI	Ploss	VPI	LBI	Ploss	VPI	LBI	Ploss	VPI	LBI	Ploss	VPI	LBI
10%	107.58	0.482	3.071	139.09	0.89	3.1	108.83	0.58	3.17	111.63	0.82	2.51	121.18	0.94	2.88
20%	90.38	0.442	2.6	115.31	0.79	2.56	92.84	0.53	2.71	94.92	0.76	2.04	96.97	0.82	2.26
30%	82.94	0.422	2.3	97.46	0.71	2.18	80.23	0.49	2.37	80.01	0.72	1.69	77.05	0.71	1.84
40%	72.49	0.406	2.013	83.98	0.607	1.92	71.82	0.45	2.16	70.87	0.67	1.43	61.44	0.58	1.54
50%	67.36	0.406	1.88	75.15	0.529	1.73	67.36	0.44	1.99	58.94	0.63	1.2	50.24	0.47	1.31

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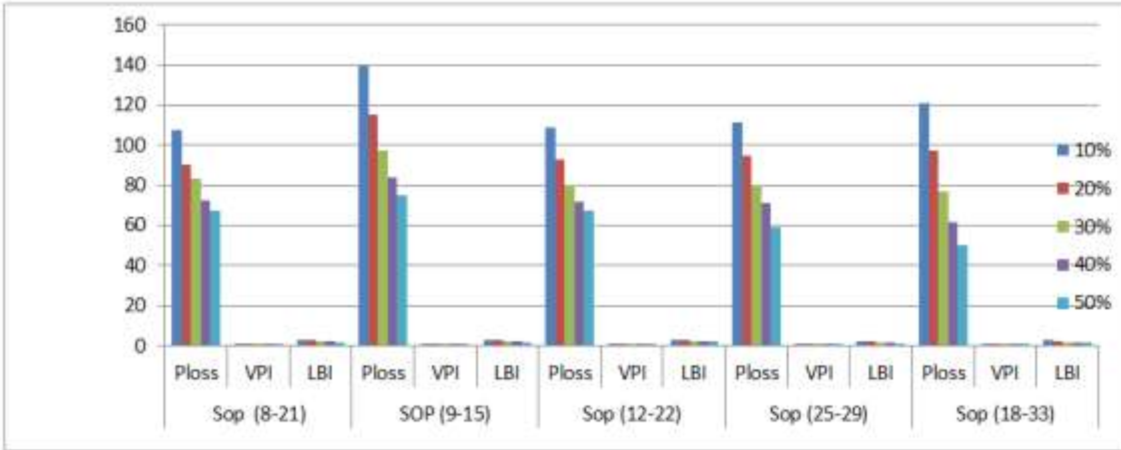

Fig.7. Deviations of the objective functions with increased DG power capacity for the all candidate places of SOP using MOPS

Table 5. Objectives obtained using PSO method with DG penetration (10%-50%)

%DG	SOP at (8-21)			SOP at (9-15)			SOP at (12-22)			SOP at (25-29)			SOP at (18-33)		
	ploss	VPI	LBI	ploss	VPI	LBI	ploss	VPI	LBI	ploss	VPI	LBI	ploss	VPI	LBI
10%	104.946	0.479	3.055	137.93	0.888	3.072	108.355	0.58	3.169	115.54	0.809	2.468	120.59	0.94	2.75
20%	90.19	0.441	2.6	114.97	0.786	2.561	92.29	0.53	2.711	94.255	0.765	2.041	96.46	0.82	2.243
30%	78.96	0.415	2.253	96.72	0.689	2.171	80.128	0.488	2.364	79.65	0.721	1.684	76.785	0.7	1.837
40%	71.165	0.403	2	82.99	0.601	1.895	71.73	0.459	2.126	67.68	0.678	1.396	61.365	0.58	1.53
50%	66.67	0.403	1.863	73.61	0.52	1.721	66.96	0.442	1.99	58.288	0.636	1.175	50.061	0.47	1.318

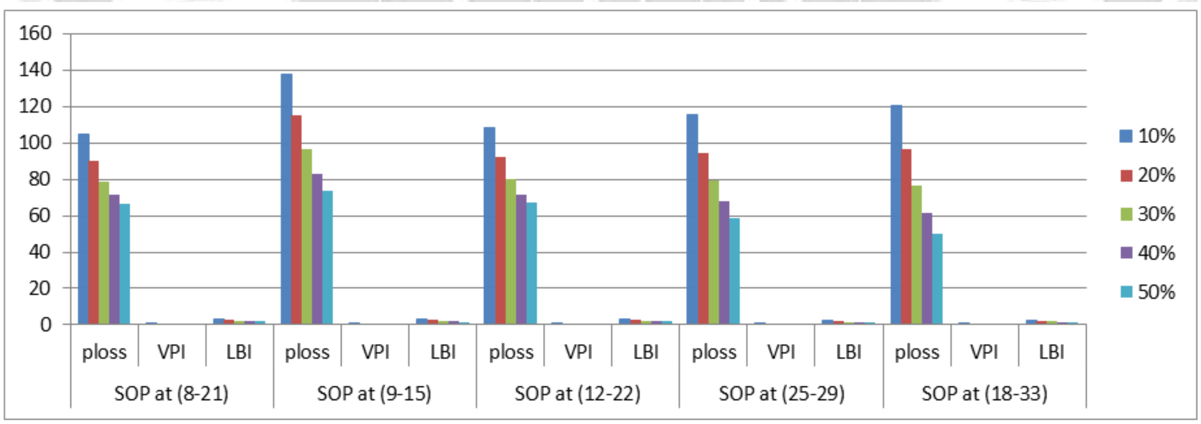

Fig.8. Deviations of the objective functions with increased DG power capacity for the all candidate places of SOP Using PSO.

Results for one of the SOP location, line (8-21), is summarized in Table 6 below. Along with the results obtained, the percentage improvement in each objective function is presented. The results are shown for both approaches adopted in this study, that is SOP and MOPSO for each

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مـــجلـة جـــامعة بـــــابـل للعلـــــوم الهندسية
Vol. 32, No. 1. \ 2024 ISSN: 2616 - 9916

percentage of DG capacity. It is clear that the percentage of improvement for the three objective functions as a result of using MOPSO, starts to increase starting from 10% penetration rate and up to 50%. This is also true for PSO, but here the percentage of improvement for each objective function is separately determined. From this comparison the results appear better in the case of using PSO than using MOPSO

Table(6) comparison of three objective function using PSO,MOPSO for one site of SOP (8-21) between without DG penetration and with DG penetration for ratio percentage (10%-50%)

	DG penetration%	10%	20%	30%	40%	50%
MOPSO (Ploss,VPI,LBI) (without DG)	(124.81,0.527,3.622)	--------------	--------------	--------------	--------------	--------------
MOPSO (Ploss, VPI ,LBI) (with DG) **Improv. Ploss %** **Improve.VPI%** **Improve.LBI%**	--------------	(107.58,0.48,3.07) 13.8% 8.53% 15.21%	(90.38,0.44,2.6) 27.588% 16.12% 28.21%	(82.94,0.422,2.30) 33.54% 19.92% 36.49%	(72.49,0.406,2.01) 41.92% 22.96% 44.5%	(67.36,0.406,1.8) 46.03% 22.96% 50.3%
PSO (without DG) **Optimizing Ploss** **Optimizing VPI** **Optimizing LBI**	(123.355,0.95,3.84) (187.42,**0**.52,6.09) (138.88,1.211,3.62)	--------------	--------------	--------------	--------------	--------------
PSO(with DG) **Optimizing Ploss** **Improve.Ploss%**	--------------	(**104.94**,0.895,3.38) 14.92%	(**90.18**,0.78,2.8) 26.8%	(**78.96**,0.72,2.42) 35.9%	(**71.16**,0.67,2.16) 42.3%	(**66.67**,0.60,2.00) 45.95%
Optimizing VPI **Improv.VPI%**	--------------	(181.39,**0.47**,5.718) 9.6%	(144.3,**0.44**,4.58) 15.3%	(126.6,**0.41**,4.03) 21.1%	(104.56,**0.40**,3.31) 23.0%	(92.57,**0.40**,2.91) **23.07%**
Optimizing LBI **Improv.LBI%**	--------------	(117.64,1.06,**3.05**) %15.7	(102.29,0.96, **2.6**) 28.17%	(89.75,0.89,**2.25**) 37.8%	(82.81,0.80,**2.00**) 44.7%	(74.86,0.72,**1.86**) **48.61%**

6.Conclusion

Investigations are implemented on the performance of a distribution system with soft open points. A simple model is used that represents the SOP as power injectors/suppliers at/from a specified location. Five different sits for SOP were investigated in the selected distribution network, and it is concluded that the SOP site plays a significant part on the amount of improvement in the operation and optimization of the network. Results obtained by applying PSO, which optimizes one cost function at a time, revealed that the percentage improvements in (Ploss, VPI ,LBI), for the case of using one SOP, considering site (8-21) as an example with a DG penetration capacity of 50%, are (45.95%, 23.07 %, 48.61%) compared to those values for base case with no SOP and DG penetration. This indicates the superiority of SOP to impact positively the three objective functions. A comparison between employing single objective particle swarm optimization method (PSO) on the network, using injected power for each VSCs as a decision variable, with a Multiple objective Particle Swarm Optimization method (MOPSO) confirms better results in favor of PSO. Results showed that the three objective functions were better using PSO compared to MOPSO. It is also concluded that as DG percentage penetration increased, percentage improvement for each objective function also increased . This conclusion coincides for both single PSO and MOPSO. The present study provides a platform procedure for obtaining reference power settings for VSC control system designs.

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التشغيل الامثل لنقاط الفتح الناعمة في شبكات التوزيع باستخدام طريقة تحسين الهدف الفردي وطريقة التحسين متعددة الأهداف لخوارزمية حركة الجزيئات الامثل

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الخلاصة

أصبحت شبكات توزيع الطاقة الكهربائية نشطة بشكل متزايد من خلال دمج وحدات التوليد الصغيرة. ومع ذلك، فإن طوبولوجيا شبكة التوزيع قد تعيق التكامل واسع النطاق لوحدات التوليد، مما يقلل من فوائد شبكة التوزيع النشطة. تعتبر النقاط المفتوحة الناعمة (SOPs) أحد الحلول للتخفيف من إعاقة تكامل المصادر المحلية عن طريق تغيير طوبولوجيا الشبكة الموزعة.

في هذا البحث، تم تحليل ودراسة مشكلة إيجاد نقاط التشغيل المثلى لإجراءات التشغيل المعيارية (SOPs). تم اعتماد نهجين؛ الأول هو باستخدام تحسين سرب الجسيمات ذو الهدف الواحد (PSO) و الثاني هو ذو الاهداف المتعددة (MOPSO).في الطريقة الأولى، يتم تحسين مجموعة الأهداف على أساس واحد تلو الآخر، بينما في الطريقة الثانية، يتم تحسين مجموعة الأهداف معًا في نفس الوقت. مجموعة الأهداف النموذجية هي: تقليل فقدان الخسائر المقاومة، وتحسين قيم الجهود، وموازنة حمل فروع التغذية. تم اعتماد المنهج المقارن في هذا البحث بهدف إيجاد أفضل نهج يحقق النقاط المثلى. النقاط المثلى التي يتم تعريفها على أنها مجموعة من القدرات الفعالة/غير الفعالة لكل محول لإجراءات التشغيل المعيارية . يتم استخدام هذه النقاط المثالية أيضًا من قبل المصممين كإعدادات مرجعية لنظام التحكم الذي يحكم التشغيل المحلي لنظام SOP.

تظهر نتائج عمليات المحاكاة التي تم إجراؤها على نظام ناقل 33 IEEE بدون ومع مصادر طاقة محلية متعددة السعة، أن الأهداف الثلاثة تم تحسينها بشكل أفضل باستخدام PSO مقارنة بـــ MOPSO مع الأخذ في الاعتبار أن PSO يتطلب جهدًا حسابيًا أقل مقارنةً بـــ MOPSO. علاوة على ذلك، لوحظ أداء أفضل لـــ PSO مع زيادة كمية الطاقة المحقونة بواسطة المصدر الموزع (DG). وينطبق الأمر الأول أيضًا عندما يتم تحسين النظام بواسطة MOPSO.

الكلمات الدالة: نقاط الفتح اللينة ,مولدات التوزيع , طريقة التحسين الفردية ,طريقة التحسين متعددة الاهداف , التحسين ,اعادة هيكلية الشبكة, محول مصدر جهد متتالي , اجهزة تحويل القدرة الالكترونية.