DG ALLOCATION AND OPTIMAL COST ANALYSIS IN THE DISTRIBUTION SYSTEM USING OPTIMIZATION TECHNIQUES

B. Nikhitha, PG Student, Electrical and Electronics Engineering, PVKK Institute of Technology, Ananthapur, India :nikhithabandaru03@gmail.com

Abstract: - Distributed generation (DG) is expected to have a substantial impact on the power networks all over the world. By deploying DGs in the distribution network, network dependability is increased. These benefits include loss reduction, backup power supply, and real, reactive power management. Power loss minimization, voltage profile enhancement, and operating cost minimization are a few of the numerous objectives of this effort that are constrained by equality and inequality. 33 bus radial distribution test systems have been used to demonstrate the suggested technique. Each test is taken into consideration for the appointment of type 1 DGs (only real power injection), type 2 DGs (both real and reactive power booster), and type 3 DGs (only reactive power injection). The simulated outcomes of the recommended approach are contrasted with those of other widely used methods.

Keywords: DG placement, SIA, CSA, optimal location and sizing of DG, power loss reduction and voltage stability improvement, radial distribution system, operating cost minimization, MATLAB**.**

Introduction

The use of renewable energy sources, such as solar, wind, biomass, hydro, geothermal, and ocean energy, is one of the most compelling arguments for study on the integration of distributed energy resources to the power grid. Renewable energy is defined in its most basic form as clean, primary, or limitless energy that is reduced in size and spread over the earth [1]. Therefore, the only method to access these resources is through having Distributed Generation (DG) add them to the distribution network[2].

Although there is significant debate regarding the precise definition of "DG," there have been some important definitions of the concept in the literature [3]. A small-scale source (10 to 10,000 KW), DG is not centrally planned or dispatched and is often directly connected to the electricity grid near the site of the end users [4]. It is projected that GD will play a big role and grow into one of the most fascinating research disciplines in the study of power production. Rising electricity demand, the ongoing focus on possible advantages, and technical and financial barriers to the construction of new power plants and transmission lines are all contributing factors [5].

The following reasons are the primary drivers of DG's rising popularity:

i. It is simple to locate and put up small generators like DG.
ii. Plants with capacities between 10KW and 15KW are now possible thanks to modern technology.
iii. Transmission and distribution (T&D) costs can be disregarded or minimised because DG units are located closer to customers.
iv. Natural gas, a common fuel for DG, is widely available and is anticipated to have stable costs.
v. The installation times for DG are quick and the investment risks are low.
vi. DG offers a variety of groupings for engineer developers to choose from in terms of cost and consistency.

In order to identify the buses in radial networks that are most susceptible to voltage collapse, load-flow equations must first be made simpler. However, no DGs are displayed. An comparable two-bus distribution network system for voltage stability improvement is given in the absence of DG penetration. Without taking into account the behaviour of radial distribution networks, bus indices for analysing how aggregated DGs affect a transmission grid's voltage security are established. To reduce system power losses, some work has been suggested for the ideal placement of the DG [6]. On a radial feeder with a non-uniformly distributed load, a DG allocation algorithm is described for voltage profile improvement and power loss reduction; however, the load variability is not taken into account. Additionally, the utility advantage is better represented by minimising the cost of energy losses.

Swarm intelligence is a branch of nature-inspired meta-heuristics that aims to emulate animal problem-solving abilities and has gradually gained popularity. Some well-known algorithms that imitate animal behaviour in problem conceptualization and solving include particle swarm optimisation, artificial bee colony optimisation, ant colony optimisation, etc. We introduce the Cuckoo Search method (CS), a brand-new population-based search method, in this research. The brood freeloading breeding behaviour of persuaded cuckoo species serves as a catalyst for this assessment of the DG site and size in the distribution chain. Because there are fewer parameters to be adjusted in CS than in other optimisation techniques, the optimisation can be solved quickly with CS. Simulation work is done on a 33-bus radial distribution feeder to verify the efficacy of the planned route. The results showed that CS is capable of handling complex optimisation problems and offers better-quality solutions with a greater precision factor than GA and PSO techniques.

The cuckoo search algorithm's beauty and simplicity are primarily responsible for the idea of this work. The organisation of the paper is briefly discussed, the problem formulation is covered in detail in the second chapter, the three algorithms are covered in detail in the third chapter, which also includes the results and discussion, and the conclusion is covered in the fourth chapter.

2.Problem formulation

The allocation of DG for a balanced distribution system is the subject of this section. It is time to begin with the goal functions, DG limitations, Voltage limits, and the load flow solution method.

2.1 Objective Function

Theobjectivefunctionforthebalancedsystemisdefined as

$$\min (P_{\text{loss}}) = \sum_{i=1}^{n} {I_i}^2 R_i \quad (1)$$

where, i is the bus number, I_i is the branch current, R_i is the branch resistance and n are the number of branches.

2.2 Constraints:

The constraints are

Voltage Constraints:

$$0.9 \leq V_k(pu) \leq 1.1 \qquad (2)$$

DG limits:

$$60 \leq P_{DG} \leq 1500 \qquad (3)$$

2.3 Loadflowsolution:

A new load flow method of analysis for radial distribution systems was proposed by J.H. Teng. The link between branch currents and bus voltage is described by matrices named BIBC and BCBV, which are expressed as [7].

$[B]=[BIBC][I]$ (4)

$[\Delta V]=[BCBV][B]$ (5)

Combining(4) and(5) we get

$[\Delta V]=[BCBV][BIBC][I]$ (6) $[\Delta V]=[DLF][I]$ (7)

The load flow solution of the distribution system is obtained by solving below equations (10), (11) and (12) iteratively.

$[{}^{I}Ii^{k}]=(Pi+jQi)/(Vi^{k})^{*}$ (8)

$[\Delta V k+1]=[DLF][I_{k}]$ (9)

$[\Delta V_{k+1}]=[V_{\circ}]-[\Delta V_{k+1}]$ (10)

2.4 Voltage Stability Index:

Each receiving node in a radial distribution system is supplied by a single sending node. The voltage stability index (VSI), which was available to Charkravorty and Das, will change once the DG is connected to the distribution system. To calculate the load flow for radial distribution systems, the equations that were utilised to construct this index are published in. Equation (6), which represents the VSI, is formed by applying Equations (4) and (5) as follows:

$$I_{ni}=\frac{V_{mi}-V_{ni}}{R_{ni}+jX_{ni}} \quad (11)$$

$$P_{ni}(ni)-jQ_{ni}(ni)=V_{ni}*I_{ni} \quad (12)$$

$$VSI(ni)=|V_{mi}|^{2}-4[P_{ni}(ni)R_{ni}+Q_{ni}(ni)X_{ni}]|V_{mi}|^{2}-4[P_{ni}(ni)R_{ni}+Q_{ni}(ni)X_{ni}]^{2} \quad (13)$$

where V_{mi}, is the sending node voltage; while V_{ni}, P_{ni}, Q_{ni}, R_{ni}, and X_{ni} are voltage, real power, reactive power, resistance, and impedance for the receiving node [8].

The index is modified to become an objective function for improving VSI, as follow:

$$f_{2}=\frac{1}{\min(VSI(ni))}n_{i}=2,3,\ldots,n_{n} \quad (14)$$

where VSI (ni) > 0 for i = 2, 3..., n, so that a feasible solution is existed. It is very essential to recognize weak buses for nodes with minimum VSI that are disposed to voltage instability. Inspecting the VSI performance exposes that the buses which undergoing huge voltage drops are weak and within the condition of corrective actions.

2.5 Cost of energy loss reduction

In order to read real power losses, the load flow solution for the test system is first solved without the use of a DG, and the process is then again represented by the net loss reduction provided by equation[9].

$NLR=P_{loss}-P_{loss,DG}$ (15)

where *NLR* = net loss reduction, P_{loss}= power loss of the system without DG, *and* $P_{loss;DG}$=power loss of the system with DG. The obtained loss reduction with DG is converted in to cost value.

C_{NLR}¼NLR×ðCostofenergysaving=kwhp×8760 (16)

The invested cost of optimally placed solar PV-type DG iscalculated

$C_{DG;\,Inv}$¼ð*DGsize* × ð*DG*Investment*Cost*=kwh (17)

The economic validation of the above discussed objective function depends on the optimal location and rating of DG.

2.6 Case study

In fact, this study takes into account three test instances. The first test case and second test case, respectively, are represented by three various DG applications [10]. For immediate use, Type 1:DG is capable of providing only real electricity from photovoltaic and microturbines. Type 2: DG can deliver both reactive and actual electricity. Biomass-based synchronous generators powered by gas turbines may be used. Only reactive power can be supplied by Type 3:DG. The type 2 DG is supporting both real and reactive power in this study. Each test case has included the installation of both a single and numerous DG units. Only two units of DG can be installed at once in the network in this investigation.

Cuckoo Search Algorithm

The broodparasitism practised by cuckoo species, which deposit their eggs in the nests of other host birds, served as the inspiration for the Cuckoo Search (CS) optimisation algorithm. Yang and Debin made the CS proposal in 2009[14], and it has already proven to be an effective solution to engineering optimisation issues. For instance, when handling the issues of designing welded beams and springs, CS produced better-quality results than the previous algorithms in [15]. If a host bird finds foreign eggs in its nest, it will either throw the eggs away or abandon the nest and create a new one somewhere else. Each host bird egg in a nest signifies a solution, but a cuckoo egg cell symbolises a fresh theory. The objective is to provide new, potentially superior solutions in place of the poorest existing ones in the nests. Although the technique can be improved to accommodate the case of numerous eggs, in this study the simplest approach is employed where each nest only has one egg.

The three idealised rules are described as follows to make it easier to explain CS.

i. Each cuckoo only ever lays one egg at a time, and she places it in a nest that is picked at random.
ii. According to the algorithm, the best nests and best eggs (solutions) will be passed down to the following generations.
iii. Although the number of host nests that can be used in this scenario is fixed, the host bird has two options: either it can abandon its nest and start a brand-new nest somewhere else, or it can simply throw the eggs away.

When generating new solutions $x^{(t-1)}$ for a cuckoo I, a Levy flight is performed.

$X_i^{(t+1)} = x_i + \alpha \oplus Levy(\lambda)$

It is basically the stochastic equation for random walk, which is a Markov chain whose next status or location only depends on the current status or location, and the transition probability, which are the first and second terms, respectively. Where > 0 is the step size that should be associated to the problem of interest's scales; can be set to value 1 in most situations [11].The result is an entry-wise multiplication, much like those employed in PSO. Since random walk through Lévy flight has longer steps overall, it is more effective at scouring the search space.

A Lévy distribution with infinite variance and infinite mean is used to derive the random step size of a Lévy flight, which essentially gives a random walk.

Levy~u=$t^{-\lambda}$

A random walk evolution with a power law step length distribution and a heavy conclusion is fundamentally formed by the successive hurdles of a cuckoo in this situation. By doing a Lévy walk close to the best answer found, several new solutions should be produced, accelerating the local investigation. However, a significant portion of the new solutions must be produced by far field randomization, so that the locations would be sufficiently remote from the present best solution, to ensure the algorithm won't be locked in a local optimum.

Cuckoo Search for Distributed Generation placement: The application of CS for optimal siting and sizing DG problem required the determination of several steps of procedure as presented for the CS parameters setting. The number of nests, n=20, stepsize,=1, and the probability to discover external eggs, Pa=0.6 have been useful in this study. In contrast, load flow analysis based on network topology based on the forward/backward sweep method was employed to evaluate the objective function due to its computational efficiency, low memory consumption, and robust convergence feature [13].

***Step1*:Initializepopulation**

The initial population will be evaluated during the objective function, which is the driving force behind CS, so the algorithm must be given the population number, n, and the initial range of host nests at the start, which can be specified by the user. If the user does not suggest any initial range, the algorithm will create an initial population with the default value.

***Step2*:Generationofcuckoo**

The cuckoo is produced at random via Lévy flight. In order to assess the quality of the solution, the cuckoo is evaluated using the load flow and objective functions.

***Step3*:Replacement**

The quality of the new solution in the randomly chosen nest must be superior to the previous

solution for the old solution (a cuckoo) to be replaced.

***Step4*:Generationofnewnest**

Based on the probability (Pa), the worse nests are abandoned and new ones are constructed.

***Step5*:Termination**

In this investigation, a tolerance value of 1e-6 and a cap of 100 iterations are used as the stopping criteria. The loop will end once the stopping requirement has been met, and the CS result will then be obtained.

SIMULATIONRESULTS

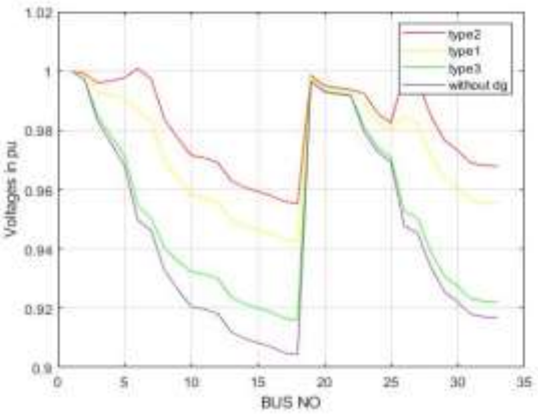
The proposed approach is tested on the depicted 33-bus radial distribution system. All network buses are presumptively powered by the substation installed at node1.The 33 radial distribution system has a 0.201MW total real power loss. Determine the price for installing DG on each model.

The Cuckoo Search algorithm, which is a self-developing code built using MATLAB script functions, was used to directly obtain the optimal siting and sizing of DG in the distribution system with the goal of minimising the total real power losses and improving voltage stability while maintaining the acceptable voltage limit.

Table I : Simulation Results of algorithm over different test cases for multiple DG

DG Type	SYS no:	DG loc	Algorithm	Real Power loss(KW)	Energy Loss (Mega Joules)	DG Cost In Rupees $\times 10^4$	DG sizing(MVA)		Percentage loss reduction(%)
N	33	NA	Base	211.07	8.5611	NA	NA	NA	NA

A				Case	8							
						Energy loss convergeby dg1	**Energy loss convergedby (dg1+dg2)**	**Cost of dg1**	**Cost of (dg1+dg2)**			
1	33	6	30	PSO	91.23	4.818	3.7815	2.6077	3.936	1.3038	0.6642	56.77
2	33	6	30	PSO	39.74	3.8487	1.0122	2.5613	4.5858	1.2806	1.0122	81.17
3	33	6	30	PSO	142.151	6.3409	5.7655	2.8285	3.8726	1.4142	0.5218	32.65
1	33	6	30	CSA	90.77	4.818	3.7002	2.6077	3.7697	1.3038	0.5810	56.99
2	33	6	30	CSA	38.51	3.8487	1.612	2.5613	4.3734	1.2806	0.9061	81.75
3	33	6	30	CSA	141.778	6.34	5.7504	2.8285	3.8176	1.4142	0.4946	32.83



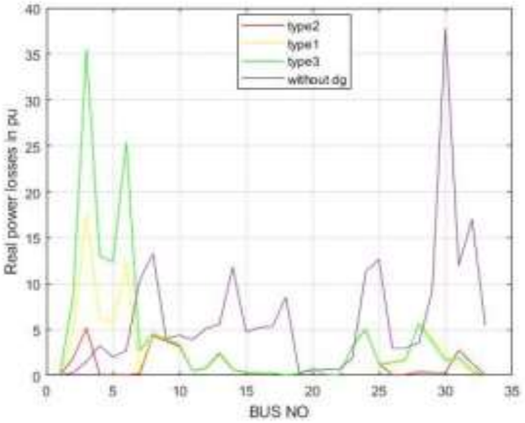
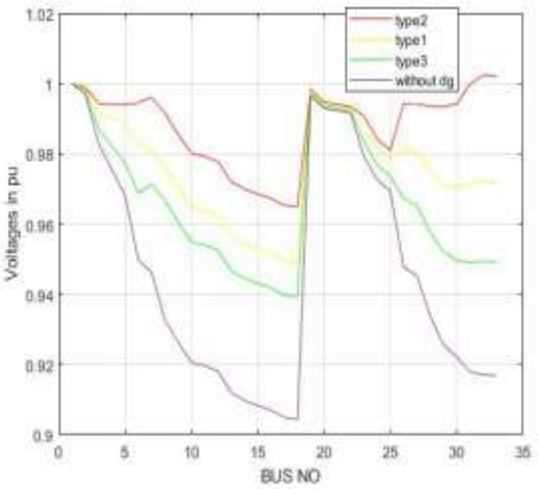


Figure 1Voltage profile for different test cases on Stability index

Figure 2Real power losses for different test cases on Stability index



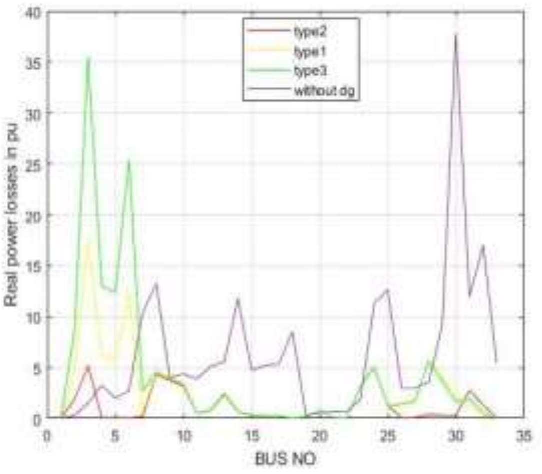


Figure 3Voltage profile for different test cases on Cuckoo search

Figure 4Real power losses for different test cases on Cuckoo search

CONCLUSION

In order to lower overall real power losses and increase voltage stability with an impending voltage constraint, a Cuckoo Search method (CS) for the placement and size problem of DGs in the radial distribution system is proposed in the research. The CS provides the DG as the productions with both the best position and size. By comparing the results between pre and post-DG installation and computing the cost at each test case, it is shown that the proposed method can minimise maintenance costs while improving voltage stability, voltage profile, and savings on power. On the other hand, when it comes to producing high-quality solutions, CS excels above SIA. However, practical limitations may prevent the ideal location or size from always being possible. For instance, the ideal size for some DG resources could not be offered on the market. The additional benefits of DG, including as its economic and environmental benefits, are not taken into account in the current study. Additionally, the use of CS in conjunction with other algorithms may open up an intriguing topic for future study.

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