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Research Article

Optimum Location of Distributed System Using Shuffled Frog Leaping Algorithm

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ABSTRACT

This paper presents a novel optimization algorithm for optimizing the distributed generation (DG) parameters in deregulated power system which improves the stability, reduces the losses, and also expands the cost of age. The shuffled frog leaping algorithm used to optimize the various DG parameters simultaneously. The various parameters taken into consideration are their type, location, and size of the DG devices. The simulation was performed on a distribution system and modeled for steady-state studies.

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INTRODUCTION

Nowadays, the power electricity demand is growing fast, and one of the main tasks for power engineers is to generate electricity from renewable energy sources to overcome this increase in the energy consumption and at the same time reduces environmental impact of power generation. The utilization of renewable sources of vitality has achieved more noteworthy significance as it advances practical living and with a few exemptions (biomass burning) does not contaminant. Sustainable sources can be utilized as a part of either little scale applications far from the substantial estimated age plants or in expansive scale applications in areas where the asset is plenteous and extensive change frameworks are utilized.

In any case, issues emerge when the new age is coordinated with the power dispersion arrange, as the customary dissemination frameworks have been intended to work radially, without considering the mix of this new age later on. In outspread frameworks, the power streams from upper terminal voltage levels down to clients arranged along the spiral feeders. In this manner, over current insurance in spiral frameworks is very clear as the blame current can just stream one way. With the expansion of infiltration of distributed generation (DG), circulation systems are getting to be plainly like transmission systems where age and load hubs are blended ("work" framework) and more intricate assurance configuration is required. In this new configuration, design considerations regarding the number, size location, and technology of the DG connected must be taken into account as the short-circuit levels are affected and miss coordination problems with protection devices may arise.

The term DG is frequently used to portray a small-scale electricity generation. However, what exactly is small-scale electricity generation? Currently, there is no consensus on how the DG should be exactly defined. As shown by the survey conducted by CIRED, there is no consensus on the definition of this term. Some countries define DG on the basis of the voltage level, whereas others start from the principle that DG is connected to circuits from which consumer loads are supplied directly. Other countries define DG as having some basic characteristic (for example, using renewables, cogeneration, being non-dispatch able, etc.).

This paper presents survey works and a methodology for optimizing a utility-owned DG size and location on the basis of economic considerations under existing loading patterns. DG is considered as voltage regulation equipment and also a backup generation to enhance supply reliability and to reduce energy losses in the distribution network as well. From this perspective, different DG schemes are available that can be compared on the basis of their direct or surrogate financial performance in terms of voltage quality and reliability costs, energy losses and DG capital investment cost and power operation cost. Indeed, recently, a few studies have presented DG allocation while considering the optimal performance of the network, in which the power quality and reliability of the network are optimized simultaneously.

This paper is organized as follows: Section II describes literature survey about DG placement and optimization problems general mathematical model of DG and renewable sources are presented in Section III. Section IV describes proposed optimization method. Section V shows Matlab results. Section V concludes the paper.

RELATED WORKS

In the study of Azizi *et al*.,[1] the authors proposed a trade-off between voltage regulation and power oscillation damping is achieved by cooperative effort of excitation and STATCOM. In the study of Azizi *et al*.,[2] a new optimization algorithm teaching- and learning-based optimization has been implemented to solve optimal multidistributed generator (DG) placement problem has been presented. This problem has been formulated for minimization of loss, capacity release of transmission lines, and voltage profile improvement. In Effect of Distributed Generator on the Allocation of D-STATCOM in Distribution Network,[3] author studied the D-STATCOM allocation problem to mitigate the voltage fluctuation on the distribution system and the effect of the DG on the proper location and the economical size. In the study of Wang *et al*.,[4] the authors recommended a model predictive control-based voltage/var optimization technique considering the integration of distributed generators and load-to-voltage sensitivities. The brief schedules optimal tap positions of on-load tap changer and switch statuses of capacitor banks based on predictive outputs of wind turbines and photovoltaic (PV) generators. In Tolabi *et al*. study,[5] a combination of a fuzzy multiobjective approach and ant colony optimization as a metaheuristic algorithm is used to solve the simultaneous reconfiguration and optimal allocation (size and location) of PV arrays as a DG and distribution static compensator (DSTATCOM) as a distribution flexible ac transmission system device in a distribution system.

In the study of Bloemink and Green,[6] authors presented benefits of distribution level power electronics for supporting DG growth. In Voltage Sag and Swell Mitigation Using DSTATCOM in Renewable Energy Based Distributed Generation Systems,[7] the voltage sag and swell issues are investigated. The first studied scenario is related to the disturbance of the energy source and the second one is due to the installation of a heavy load with a sensitive load at the same supplying bus. In Bouhouras study,[8] the author presented a new approach to the optimal placement of a step voltage regulator taking into consideration the installation of DG based on a genetic algorithm. In the study of Masaud *et al.*,[9] the authors found that the reactive power absorbed by SCIG is supplied by DFIG, and therefore, the combined system operates at unity power factor, which makes it feasible to comply with the IEEE 1547 standard. In the study of Mistry and Roy,[10] the authors utilized two novel optimization techniques, namely, particle swarm optimization (PSO) and craziness-based PSO to find the optimum location and optimum size of single and two DG in distribution system. Minimization of active power loss in distribution network is carried out through DG placement. In the study of Nazaripouya *et al*.,[11] they proposed a new strategy to achieve voltage regulation in distributed power systems in the presence of solar energy sources and battery storage systems. The goal is to find the minimum size of battery storage and its corresponding location in the network based on the size and place of the integrated solar generation. This method formulates the problem by employing the network impedance matrix to obtain an analytical solution instead of using a recursive algorithm such as power flow. In the study of Othman *et al*.,[12] authors presented an efficient and fast-converging optimization technique based on a modification of the traditional big bang-big crunch method for optimal placement and sizing of voltage controlled distributed generators. In the study of Roy *et al*.,[13] they presented the application of FACTS devices for the enhancement of dynamic voltage stability in distribution networks with distributed wind generation. In D-STATCOM Control in Distribution Networks with Composite Loads to Ensure Grid Code Compatible Performance of Photovoltaic Generators,[14] they proposed an optimal linear quadratic Gaussian controller for D-STATCOM to improve the dynamic performance of distribution networks with PV generators. In the study of Niknam *et al*.,[15] they proposed a multiobjective optimal location of automatic voltage regulators in distribution systems at the presence of DGs by a fuzzy adaptive PSO algorithm. The proposed algorithm utilizes an external repository to save founded Pareto optimal solutions during the search process. The proposed technique allows the decision maker to select one of the Pareto optimal solutions (by trade-off) for different applications.

MATHEMATICAL MODEL

DG devices

The DG size is very important for placing it in a particular bus as the losses decrease to a minimum value and start increasing above the size of DG (i.e., the optimal DG size) at that location. The expansion in estimate prompts boosts the misfortunes esteem, and it might overshoot the estimations of the misfortunes in the base case. The best possible area of DG assumes a vital part in limiting the misfortunes, expanding the client advantage, and limiting the voltage deviation index.

The modeling of DG is very essential to reach the objective. The unity power factor modeling is done in PV cell, wind as a variable reactive model and gas turbine is modeled as a constant voltage model. A DG source has a constraint and it can be formulated as:

$$P_G^{min} \le P_G \le P_G^{max}$$

The reactive power of the DG is considered with output as playing main role. The bus connected to the DC can be modeled based on their characteristics in terms of real and reactive power delivering capability as three categories:

1. Type 1: DG which injects real power only.
2. Type 2: DG which injects reactive power only.
3. Type 3: DG injecting real power but consuming reactive power Q.

The primary energy of DG may be injected to grid by a synchronous or asynchronous electric machine which is directly connected

to the grid or by means of power electronic interface or a combination of electric machine and power electronic interface. The modeling of different DGs is done as follows: In general, DG is considered as an electric power source connected directly to the distribution system.

Modeling of PV cell

The PV framework changes over sun-powered vitality into electrical vitality. The DC control yield is changed over by means of an inverter into AC control so it is perfect with the lattice. The DG demonstrate relies on control circuit and by large it is intended to control P and V autonomously which is displayed as a PV node. When P and Q are controlled independently, it is modeled as a PQ node. The power factor is unity and the necessary condition for minimum loss is given by Equation 2.

$$P_i = P_{DGi} - P_{Di} = \frac{1}{A_{ij}} \sum_{\substack{j\neq 1 \\ j\neq i}}^{n} [\left(A_{ij}\right) P_{j-B_{ij}Q_j}] \quad (1)$$

From the above equation, we obtain

$$P_{DGi} = P_{Di} - \frac{1}{A_{ij}} \sum_{\substack{j\neq 1 \\ j\neq i}}^{n} [\left(A_{ij}\right) P_{j-B_{ij}Q_j}] \quad (2)$$

A_{ij} and B_{ij} = loss coefficients.
P_j = real power injected to bus j.
Q_j = reactive power injected to bus j.
N = number of buses.

Modeling of wind turbine

The AC output power of these units is changed over by a power electronic-based rectifier and an inverter to network good AC control. In an enlistment generator, both dynamic and responsive forces are elements of slip.

$$P = P(V,S)$$

$$Q = Q(V,S) \quad (3)$$

Where, P and Q are the active and reactive produced, the induction generator slip is denoted by "s," and the bus voltage is "V." Assuming the dependency of Q is very low and P is constant, the expression (4) can be reduced as follows:

$$P = P_s = \text{constant}$$

$$Q = f(v)$$

$$Q = \sqrt{E_q / X_d} - P^2 - \frac{V^2}{X_d} \quad (4)$$

No load voltage E_q is maintained constant and X_d is the synchronous reactance and V is the generator terminal voltage. The parameters of wind turbine include cut-in wind speed and rated wind speed and typical values of them are 3.5 m/s, 25 m/s, and 14 m/s.

$$P_{wind}(t) = 0.5\alpha\rho(t)\ A\ v(t)^2 \quad (5)$$

Where, α is the Albert Betz constant, ρ(t) is air density, A is area swept by turbine rotor, and v(t) is the wind speed. Maximum power rating of wind station is fixed by taking averages of all day powers calculated using the equation. For this type of DG, the power factor varies between 0 and 1. The maximum DG capacity for renewable DGs such as solar and wind is calculated from the average power estimated by irradiance and wind speed. The average power generated by the wind turbine is 0.471 p.u.

PROPOSED WORK

Heuristic techniques might be utilized to fathom complex improvement issues. Consequently, it can give a decent answer for a specific issue in a sensible calculation time; however, they do not guarantee to achieve the worldwide idea. The main objective of this paper is to study the effect of placing and sizing the DG in all system indices. Multiobjective optimization is performed by combining all indices with appropriate weights. The objective function is given as,

F(MIN) =(W1*PL+W2*TSW+W3*CONIND)

In the shuffled frog leaping (SFL) algorithm, each memeplex is allowed to evolve independently to locally search at different regions of the solution space. In addition, shuffling all the memeplexes and redividing them again into a new set of memeplexes results in a global search through changing the information between memeplexes. As such, the SFL algorithm attempts to balance between a wide search of the solution space and a deep search of promising locations that are close to a local optimum.

Each individual frog (solution) in a memeplex is trying to change its position toward the best frog within the memeplex or the overall best frog. As shown in this equation, when the difference in position between the worst frog X_w (i.e.,m the frog under evolution) and the best frogs (X_b or X_g) become small, the change in frog X_w's position will be very small and thus it might stagnate at a local optimum and leads to premature convergence. To overcome such an occurrence, this study proposes the various steps are as follows:

1. The SFL algorithm involves a population "P" of possible solution, defined by a group of virtual frogs (n).
2. Frogs are sorted in descending order according to their fitness and then partitioned into subsets called as memeplexes (m).
3. Frogesi is expressed as X_i = (X_{i1}, X_{i2},….X_{is}) where S represents number of variables.
4. Within each memeplex, the frogs with worst and best fitness are identified as X_w and X_b.
5. Frog with globe best fitness is identified as X_g.
6. The frog with worst fitness is improved according to the following equation.

$$(D_i) = \text{rand}()\ (X_b - X_w) \quad (6)$$

$$Xneww = Xoldw + Di(-Dmax \leq Di \leq Dmax) \quad (7)$$

Where, rand is a random number in the range of [0,1], D_i is the frog leaping step size of the i^{th} frog, and D_{max} is the maximum step allowed change in a frog's position. If the fitness value of new X_w is better than the current one, X_w will be accepted. If it

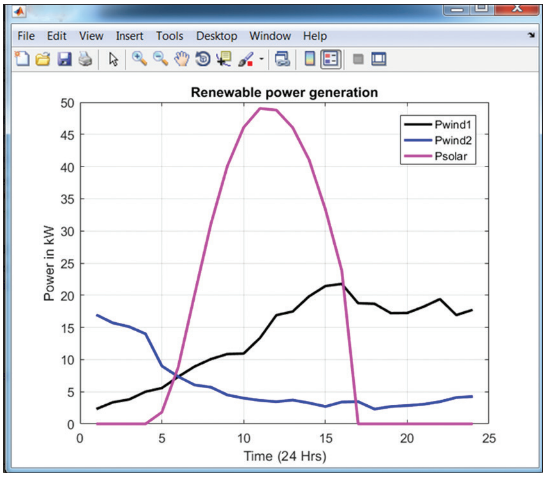

Figure 1: Power generation

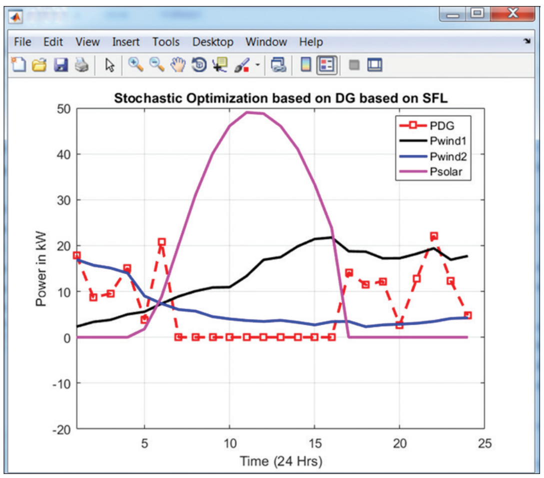

Figure 2: Optimization based on shuffled frog leaping

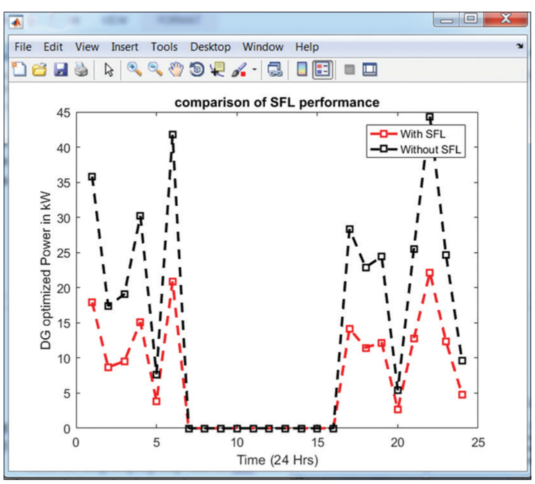

Figure 3: Shuffled frog leaping (SFL) performance analysis from Figures 2 and 3 shows considerable amount of reduction in power when applying SFL optimization.

is not improved, then the calculated (8) and (9) are repeated with X_b replaced by X_g. If no improvement becomes possible in the case, a new X_w will be generated randomly. Repeat the operation for a specific number of iterations.

After a predefined number of memetic evolutionary steps within each memeplex, the solutions of evolved memeplexes are replaced into new population. This is called the shuffling process. The shuffling process promotes a global information exchange among the frogs. Then, the population is sorted of decreasing performance value and updates the population best frog's position, repartition the frog group into memeplexes, and progress the evolution within each memeplex until the conversion criteria are satisfied.

SIMULATION RESULTS

The power flow studies are carried out with the help of MATLAB tool. The initial value of n DG as 50, which indicates the number of DG devices to be simulated and is defined as PV cell is 1, PV cell is 2, and wind turbine is 3. In the proposed optimization study for considering the power system network, the different types of DG device and their optimal locations allow maximization in customer benefit and reduction in losses [Figures 1-3].

CONCLUSION

In this paper, a proposed optimization method is found to be more efficient for solving the locations of a given number of DG devices in a power system. Two different types of DG devices are simulated for energy management: PV and wind. Furthermore, the location of DG devices, their types and rated values are optimized for different loading conditions simultaneously. The optimization strategies turn out to be the best resource when a few issues in high voltage designing and in power framework innovation cannot be tackled utilizing customary methods.

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