A Short Review on the Optimization Methods Using for Distributed Generation Planning

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Abstract- Industrial and social developments increase the need for energy. Due to the fact that fossil fuels will run out to meet energy needs, alternative technologies have been sought. Interest in renewable energy sources has increased. However, since renewable energy sources vary according to geographical conditions, their continuity must be ensured. Therefore, the focus has been on distributed generation systems. The components of distributed generation systems are divided into renewable, non-renewable and storage systems. Technical difficulties may arise in the connection of distributed generation systems with renewable resources. Therefore, it is very important to optimize distributed generation so that the distributed grid provides the expected power. Optimization systems are emphasized so as to decrease efficiency, reduce costs and cut down power fluctuations in distributed generation systems. In this study, distributed generation system, renewable energy source and energy storage system are mentioned. Metaheuristic methods for the efficiency of an energy system are studied. Evolution based algorithms can only keep the search space information in the iteration found, while swarm based algorithms can store the search space information throughout the iteration. Most metaheuristic algorithms use the biological cycle process, swarm behaviour, and physical laws. Evolution based and swarm-based optimization methods are examined in metaheuristic methods. As evolution based metaheuristic methods, genetic algorithm and swarm based optimization methods particle swarm optimization, ant colony optimization, grey wolf optimization, bat algorithm, whale optimization algorithm, cuckoo search algorithm are discussed. A general comparison of the investigated optimization methods is presented. It was concluded that the swarm optimization methods examined were able to make fast convergence and avoid local minima and computational efficiency evaluations.

Keywords : Distributed generation, renewable resources, metaheuristic algorithm, swarm optimization, optimization methods

1. Introduction

Industrial and social developments increase the need for energy. In order to come across the energy require, the existing nonrenewable energy sources are running out, and alternative energy sources and alternative technologies have started to be sought [1] It is known that in the recent past, Turkey's electricity energy transmission network has experienced overloading, serious and long term collapses as a result of faulty planning. Alike location and risks are still being valued. Otherwise, with global warming, the use of renewable energy sources is increasing rapidly in our country as well as in the world. The focus is the duality of subgrids in energy production. In short, it is necessary to plan and increase the alteration to renewable energy in the smart grids of the future [2]. Smart grids are defined as independent systems that reduce the workforce, are economically efficient, aim at high quality, provide the most appropriate and sustainable integration of energy from source to consumption.

The use of alternating current is common in the generation and supply of electricity for transmission over long distances. The disruptions are caused by the nature of centralized power systems, the level of distribution of industrial and residential customers, and the increasing amounts of generation and energy resources connected to the meter. Distributed generation (DG) has a immense affect on the future of energy systems, energy storage and demand response. DG can be defined as small scale, generally renewable energy sources and close to the load it feeds. In addition, since it includes nonrenewable energy structures, a full definition cannot be made [3].

DG networks reduce line losses, the need for the construction of new transmission lines. It can also provide reliable electricity generation. DG units provide flexibility to power system consumers and a power grid based on traditional central model [4]. The financial benefits of DG's are their electrical fees and fuel capability. Its ecological benefits are reducing the effects of pollution and green house gases [5]. In recent years, distributed generation resources must be integrated into the distribution network in order to provide many benefits such as easy connection of renewable energy sources to the system, increasing reliability and flexibility, and reducing losses. Distributed generation is an electrical power source directly linked to the distribution network or to the customer part of the meter. In distributed generation, electricity is produced close to the end users. In distributed generation, both fossil fuel based technologies and renewable energy sources such as wind and sun are used as energy sources [6]. It is an intermittent system as the production amounts of renewable energy sources vary according to weather conditions. The use of energy storage systems to assure the persistence of renewable energy sources is important in terms of environmental effects. Optimal planning is required to reduce costs and make better use of energy storage. In power distribution networks, power losses, voltage instability and poor power quality are caused by incorrect positioning and sizing of DGs. [7].

If we look at the literature studies;

The irregular nature of renewable distributed generation causes uncertainness in electricity market prices and demand fulfillment [8]. In order to model these uncertainties accurately and efficiently, optimal integration of energy resources in distributed generation is required. For this reason, an overview of distribution network planning has been made. Metaheuristic optimization methods to better adapt renewable distributed generation to the electricity grid is anallyzed in detail [9]. A modified classification is mentioned for island detection methods by dividing them into single inverter, multi inverter, AC micro grid and DC micro grid [10]. Island detection is needed because the connection requirements between the micro grid and the grid need to be updated as a result of the rapid increase in DG's in the electrical power system. A solution has been proposed for problems such as smart energy storage system selection, charge and discharge, sizing and power quality [11]. A new approach has been obtained by utilizing genetic algorithm to model planning problems for extending converged centralized system and distributed generation systems in regulated power system [12]. As a result of this approach, the superiority and effectiveness of the method were indicated. The placement and energy potential of the energy storage systems needed by the distributed generation systems in a 33 busbar system were optimized in MATLAB [13]. An optimization planning method to offset wind and PV power supply cost and avoid outages is proposed [14]. As a result of the study, it has been revealed that the penetration rate of renewable energy electricity can be improved effectively.

This article focuses on renewable distributed generation system. Energy storage systems are needed to prevent interruptions in renewable energy sources. Therefore, energy storage systems compatible with distributed generation are also briefly mentioned. Planning in the distributed generation system helps to enhance the power quality of the system, cut down the cost and regulate the voltage. Its planning can be done using optimization methods. Some optimization methods are being investigated for the accuracy of objectives such as loss reduction, voltage improvement, reliability improvement for placement and sizing of DG's. Among the metaheuristic optimization methods, genetic algorithm, particle swarm optimization, ant colony optimization, gray wolf optimization, bat optimization, whale optimization and cuckoo search algorithm optimization were investigated. As a result of the examination, it has been seen that metaheuristic algorithms are better in solving complex problems.

2. Distributed Generation

In recent years, changes have been observed in electricity supply and supply dependent transmission and distribution systems around the world. Behind these changes are technological advances, safety and emission reduction concerns. In order to address important issues such as the growth of competition in the electricity market and the development of renewable electricity generation technologies, the participation of distributed generation technologies in power systems has been increased. DG's sophistication provides benefits such as reliability, power quality and efficiency [15]. Energy distribution companies are required to connect the electricity of the producers with distributed generation to the grid. The data, features and planning of these manufacturers must be recorded by the system. Planning is very important for distributed production systems [16]. Developments in distributed generation technologies have had an affect on rising customer command, liberalisation of the electricity market and climate alter. Among these factors, liberalization of the electricity market and environmental factors will be emphasized [17,57].

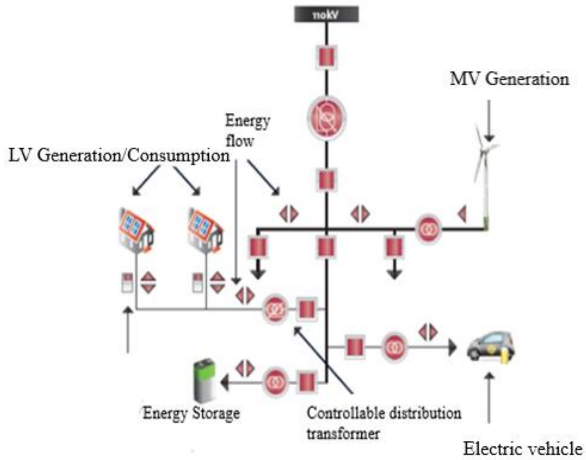

Fig. 1. Decentralized (Distributed) energy system [16].

Distributed generation is flexibly enabled to respond to changing market conditions. It is important to adapt flexibly to the economic environment in free markets. Distributed manufacturing technologies adapt to this flexibility thanks to their small size and short construction times. Distributed generation in free markets also ensures the security of energy supply. Distributed generation can also play a role, as it allows firms with a large demand for both heat and electricity to optimize their energy consumption. In terms of environmental factors, the demands of large companies to optimize energy consumption for both heat and electricity are effective in distributed production [17,61].

There are commercial, technical and environmental challenges in today's distributed generation setups. There are challenges such as rapidly increasing energy demand, environmental concerns, technical problems and renewable energy sources being an intermittent energy source. Overcoming these challenges will increase the use of DG. A power quality problem can be defined as voltage, current and frequency imbalances that will cause end consumer devices to fail or not work. The most important problem with power quality is voltage fluctuations. Another problem with power quality is long-term voltage interruptions. Detection and classification of power quality problems makes monitoring systems in the smart grid. DG's can regulate situations that change in current and voltage quality due to harmonic distortions, noise on the consumers side [18, 56]. Voltage spikes can occur at the connections of distributed generation. Incorrectly sized power supplies and poorly regulated transformers cause voltage spikes. There are negative effects such as vibration of distributed production elements and damage to sensitive equipment. [19].

The fact that renewable energy sources have an uncertain and variable production structure, leaving the system in case of failure and switching to island mode cause instability of the power system in distributed generation. [20].

Distributed generation technology is divided into three. These are renewable energy, traditional nonrenewable energy and energy storage technologies. Renewable technology includes wind, solar, biomass, geothermal, tidal and hydroelectric power. It is to benefit from the sun as PV energy and thermal. Nonrenewable technology consists of micro turbine, gas turbine etc. Storage technology consists of many storage techniques such as batteries, super capacitor, flywheels, compressed air energy storage (CAES) and pumped storage.

2.1. Renewable Energy Source

The orientation towards renewable energy sources in the world has intensified due to global warming and the depletion of fossil resources. Sustainability mainly refers to the economic, social and environmental performance of systems. Renewable energy sources are a sustainable, environmentally friendly, clean energy source. If we list the renewable energy sources; solar energy, wind energy, geothermal energy, bioenergy, hydropower and ocean energy. Advantages of renewable energy sources are environmental friendliness, reducing dependency on foreign sources, and reducing line costs by integrating with distributed energy. Its disadvantages are cost of renewable energy sources, discontinuity and geographical location limitations. Owing to the noncontinuous nature of renewable energy sources, continuity is ensured by using energy storage methods.

2.1.1 Micro Hydroelectric

In hydroelectric systems, electrical or mechanical energy is produced using running water. For micro hydro power systems in the river, some of the river water is directed into the penstock, which is delivered to the turbine. The water in motion in the penstock rotates the turbine and generates electricity by powering a generator. For mechanical energy generation, it is realized by pumping water with the movement of the shaft [21].

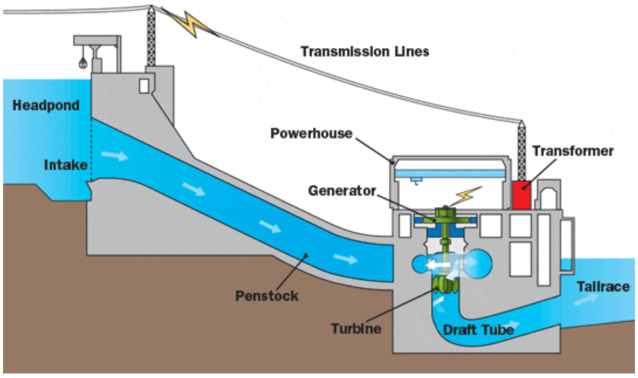

Fig. 2. Micro hydro circuit diagram.

Calculation of power and corresponding energy in hydroelectric production;

$$P_0 = \rho \cdot g \cdot Q \cdot H_0 \quad \text{(kW)} \tag{1}$$

$$E_0 = \rho \cdot g \cdot H_0 \cdot \Delta t \quad \text{(kWh)} \tag{2}$$

where H_0 is the net height, Q; represents the flow rate of the hydroelectric system.

Optimization can be made to analyze the ecological and economic trade off associated with the dam in the river system to maximize the optimal size of the hydroelectric plant, increase its stock capacity, and reduce water power losses [22].

2.1.2 Solar Power System

Electricity production from the sun takes place through solar cells (photovoltaic (PV)). Solar cells execute this transition employing semiconductor elements [23]. The solar cell, which is the most basic unit of this system, is related in series and parallel to assure that the panel has the wanted power. Among the important features of solar cells are that they are long lasting, durable and do not cause significant environmental pollution. Solar cells have low maintenance requirements and do not have any electrical problems in their operation. Solar cells, depending on their structure, can convert solar energy into electrical energy with efficiencies of 5%-20%. Effective parameters of solar cells in electricity generation [24];

- Intensity of solar radiation
- Sunbathing time
- Sun's angle of incidence
- Heat
- Structure of the material

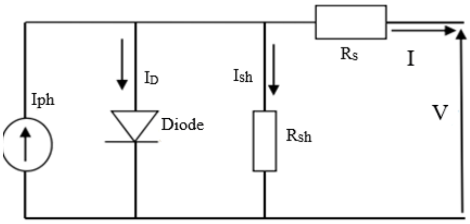

Fig. 3. Photovoltaic cell circuit diagram.

A single diode PV circuit diagram is utilized in the solar model. V signal will be the pump voltage. The relation between the signals current (I) and voltage (V) of the PV panel for a single unit is articulated as [25].

$$I = I_{Ph} - I_0 \left(e^{\frac{V+IR_s}{aV_T}} - 1 \right) - \frac{V + IR_s}{R_{sh}} \tag{3}$$

I_{Ph}, I_0 , R_s , R_{sh} and V_T were completed under standard test conditions of 1 kW/m2 air volume and 25ºC. These arguments are utilized in analytical and numerical solving.

Optimization methods are used in order to obtain maximum efficiency in solar radiation level estimation studies, considering economic, environmental, technical, social and risk criteria in order to prioritize regions for the establishment of solar power plants. Artificial neural networks, genetic algorithm and neuro-fuzzy inferences can be preferred for predictions [22,60].

2.1.3 Wind Energy System

The kinetic energy of the wind is changed into mechanical energy via the rotor. The rotating knifes of the propeller rotate the shaft inside the nacelle connected to the generator, and wind energy is produced by transferring the shaft to the generator [26,58]. In the early days, fixed speed turbines were used in wind power plants. Later on, the use of variable speed turbines with high efficiency, whose speed can be adjusted according to the instantaneous wind, has increased. Turbine and generator selection should also be adjusted according to the suddenly changing speed of the wind. The control structures used allow less costly and more efficient energy production [27].

Output power (P_W) is given by following expression

$$P_W = \frac{1}{2}\rho_w A v^3 C_p \tag{4}$$

Where ρ_w denseness of air in (kg/m^3) , A is swept area of rotor blades, C_p is power coefficient.

The power coefficient can be expressed by following equation;

$$C_p = \frac{1}{2}(\delta - 0.022\beta^2 - 5.6)e^{-0.17\delta} \tag{5}$$

Where β is slope angle of blades in degree,δ is tip speed ratio of turbine .

Optimization methods are preferred to improve the energy system voltage level in determining the switching of inputs in the electrical system design in wind farms in terms of production cost and system reliability. In addition, considering the uncertainties in wind energy production, the positioning and sizing of the storage units can be done with optimization techniques [22].

2.2. Energy Storage Technology

Technologies that can adjust system power quickly and flexibly and can be applied to power system devices are called energy storage. Energy storage technology can be applied in balancing the energy peak situations, regulating frequency, producing high quality electrical energy, providing a short term energy source separate from the grid and reducing the cost. Therefore, renewable energy is expected to replace fossil fuels [28]. Energy storage systems can improve system performance such as reliability, responsiveness and load capacity. It is an effective system in the development of renewable energy technologies [29]. Storage of energy is supplied by batteries, compressed air, flywheels, thermal power, super capacitors, super conductors and fuel cells. Energy storage technologies are seperated into three as mechanical, electrochemical and electromagnetic.

Chemical energy storage is very suitable for storing large amounts of energy and for longer periods. In chemical energy storage systems, it concentrates on hydrogen and synthetic natural gas as secondary energy carriers. It can have significant effects on the storage of large amounts of electrical energy. Hydrogen is a widely used industrial chemical. After the combustion reaction, they only release water vapor to the nature as an emission. The chemical energy of hydrogen is 142 kJ/kg, which is higher than other hydrocarbon based fuels. Hydrogen is used to power fuel cell cars, special internal combustion engines and fuel cells. Thermo chemical energy storage relies on a reversible reaction that absorbs heat energy to chemically convert it into two components.

Capacitors from electrical energy storage systems are short-lived due to their relatively low capacitance, but can be used in case of high current. The super capacitor can provide high capacitance in a small space. Super conducting magnetic energy storage systems can be favoured in industrial areas to balance energy consumption and meet peak times of energy consumption. The most beneficial advantage of mechanical energy storage is that they can easily transmit energy for mechanical work when needed. Mechanical energy storage methods can be easily adapted to change and store energy from water, wave and tidal sources. [30]. Among the energy storage systems, the methods that can be exercise in as big measure systems that have great capacity and can supplied energy for a long time are pumped hydro storage and compressed air energy storage. The most effective and economical method in large powerful systems is the pumped hydro storage system.

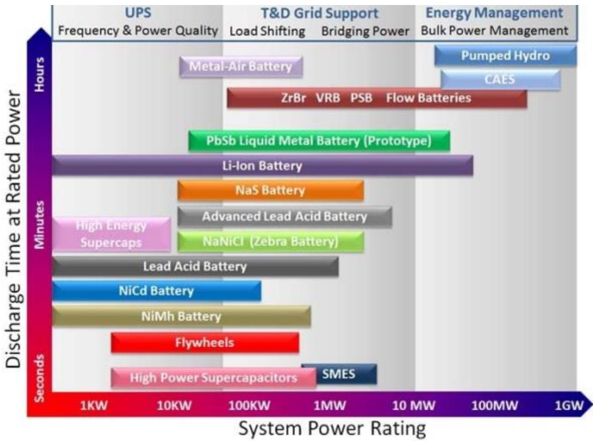

Fig. 4. Energy storage systems.

Fig. 4 gives the performance characteristics of energy storage technologies used for different applications. As can be seen, the hydro energy storage systems pumped from these systems can operate in systems with a discharge time of hours and up to GWs that can be integrated into high-power renewable systems. Storage systems with fast response, long cycle life, low cost and high energy efficiency should be preferred. Battery technologies are preferred in terms of improving frequency and power quality. For an efficient storage system, it must be able to respond to the need for change in environmental factors such as changing loads and weather conditions. It should be able to provide continuous energy and its efficiency should be increased. The energy storage system is used in transmission and distribution systems, renewable energy and large power plants. [11].

3. Optimal Planning of Renewable Distributed Generation

Optimum planning includes controlling costs, reducing energy loss and reliability costs. Planning is done to increase power quality, appropriate regulation in the energy storage system, increase power quality, reduce top out load command, reduce cost, integrate with renewable energy source and raise system effectiveness [31]. Minimum power loss is achieved by proper positioning of the DG. For positioning and sizing, it is necessary to find the power capacity and power factor. For this, optimization techniques are used. Recently, numerical based, heuristic based and analytical based methods have been used to minimize power losses in DG combined distribution networks. Numerical based algorithms are complete search, optimum power flow and linear programming. These programs aim to do suitable positioning for DG capacity. Heuristic based methods are based on computational intelligence algorithm. Thanks to the use of computational intelligence algorithms, their computational accuracy is high. Thus, it offers near optimal solutions. Smart search methods are tabu search, particle swarm optimization, ant colony optimization,bat algorithm, cuckoo search algoritm, grey wolf optimization,artifical bee colony, genetic algoritm and whale optimization algoritm. As analytical-based methods are easy and fast to implement, research on this subject has increased [32]. There are different optimization methods utilized in planning optimum size and positioning to figure out distinct DG problems.

3.1. Conventional Methods

Traditional optimization techniques are used for distributed generation planning in power distribution networks. In this section, traditional optimization techniques are mentioned.

3.1.1. Mixed Integer Linear Programming

Mixed integer linear programming (MILP) techniques include continuous and discrete decision variables. This technique is based on the linearization of the power flow. This method can be used for optimal planning of DG's to maximize profits. Linear programming techniques can produce error outputs in the linearization process. But it is suitable for handling complex problems.

3.1.2. Mixed-Integer Non-Linear Programming

Mixed integer nonlinear programs (MINLP) are a system that provides a component-traceable flexibility to solve for branching and limit and optimality. Stretches should generally be convex. Examined in the MINLP model, the final solution reported by the mixed integer convex approximation may have few prediction errors due to the approaches used in the optimal power flow problem. Optimal reconstruction problem in DC networks, existence of binary variables related to branch selection and non-linear relationship between voltage and current related to power balance for each node is represented as a mixed integer nonlinear programming model [33].

A global optimization technique is used to reduce branching using the constraints approach [34]. In order to minimize the production deficiency and emission of the energy storage system, research was carried out and the changes on the load profile of the grid were examined according to seasonal changes throughout the year.

Examined different load models using mixed integer nonlinear programming approach for voltage profile, minimizing wind turbine power fuel cost, determining optimal location of distributed generation are examined [35].

3.2. Metaheuristic Algorithms

The metaheuristic algorithm is looping which reduces cost, power errors with probability solution by connecting the derived structure. Setting the optimization parameters relies completely on setting the optimization parameters for optimality and productiveness. Some of the meta-heuristic algorithms are indicated below. Optimization algorithms define an objective function depending on the problem, and then the maximum and minimum of this objective function are found by an optimization algorithm. Optimization algorithms are used to solve engineering problems. The solution of optimization problems will be more successful by knowing which optimization algorithm to use. Recently, swarm intelligence algorithms have been widely used in solving optimization problems because of their search capabilities. These algorithms are inspired by nature; It is necessary to know how to move, find food and share information so that the background of algorithms can be simulated in mathematical forms among swarm particles [36].

3.2.1. Genetic Algorithms

A standard genetic algorithm starts with an initial set of random solutions. For the representation of each solution, the individuals in the solution set are the chromosomes. Depending on the nature of the problem, 0-1 or permutation coding is used in the representation of chromosomes. As a result of applied iterations, chromosomes are changed and new generations are formed. In genetic algorithm, crossover and mutation operators are used to change chromosomes and create new generations. In crossover, two chromosomes are paired to form sons, while mutations result in the formation of new individuals with the change in the gene. In each new generation that occurs, the solution quality of the chromosomes is evaluated with the fitness function. The crossover process continues until the chromosome giving the best solution is found. It is terminated when the specified termination criterion is met [37].

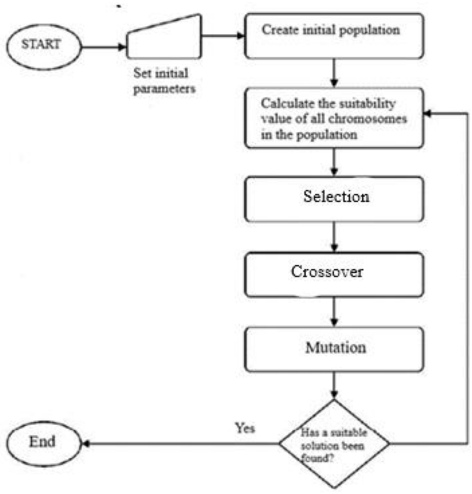

Fig. 5. GA flow chart.

Ref. [38], explored different strategies for the synthesis of energy management systems, maximizing the benefit generated by energy interchange with the grid with a genetic algorithm. As a result of the research, they have observed that even when the rule-based system is cutted down less than 30 rules, the performances are only 10% below the ideal reference solving. Ref. [39], the optimum size and location of the distributed network in order to reduce active power privations and voltage fluctuations, the construction of a 33 bus system with genetic algorithm has been investigated. Ref.[40], genetic algorithm was used in programming to analyze energy demand and cost in renewable energy parameters. Mathematical models of all loads are proposed. They also observed the objective function and analytical results to validate the simulation results.

3.2.2. Particle Swarm Optimization

Particle swarm optimization (PSO) was proposed by Eberhart and Kennedy based on the simulation of bird and fish flocks. Particle Swarm Optimization technique can be used in nature such as bees, ants, birds, etc. It is one of the techniques that emerged as a result of the examination of many herds [41]. PSO is a population-based evolutionary Global Optimization operator. In the method, a predetermined number of populations is generated in each iteration. These models are evaluated and the model parameters that make up each model are updated. The next iteration continues with the evaluation of the updated models. For a population of N models (i=1,2,…,N), the models within the population (x_i) are updated as follows, after evaluating the models produced in any iteration "t".

$$V_i(t+1) = \chi(V_i(t) + c_1\varphi_1(-x_i) + c_2\varphi_2(P_{g,best} - x_i) \quad (6)$$

$$x_i(t+1) = x_i(t) + V_i(t+1) \quad (7)$$

According to Eqs. (6) and (7), the new parameters of any model are the values of its current parameters (x_i), the best parameters it has taken up to the current iteration ($P_{1,best}$), and the model parameters of the best model obtained up to the relevant iteration. ($P_{g,best}$) is a resultant [42,59].

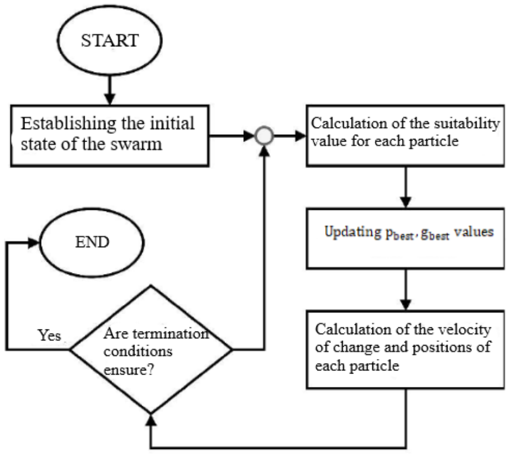

Fig. 6. PSO flow chart.

The PSO algorithm can be used to improve the voltage profile in distribution networks, to optimize the DG units, to minimize power losses, and to reduce operating costs.

3.2.3. Ant Colony Optimization

In the 1990s, Dorigo et al. recommended Ant Colony Optimization (ACO) as a newly technique for optimization problems [43]. Ant colony optimization algorithm is very suitable to be work in parallel in structure. In the colony structure, there are more than one asynchronous or parallel working ant. If it is considered that there are more than one node in the parallel ant colony (parallel system) system and it is assumed that each ant is working on a node at a certain time, ants can be qualified as intelligent intermediaries in parallel systems. Ants visit all cities starting from a randomly chosen city and leave pheromones on the roads they pass. These pheromones are effective in determining the path of the next ants, so the communication between the intermediaries leads to a common result. The number of ants in the colony is increased by finding the most allow parametric alpha (α), beta (β), ro (ρ) values used in the presumption computation within the ACO algorithm. This will increase the probability of finding the most suitable values [44].

$$a_{ij}(t) = \frac{[\tau_{ij}(t)]^{\alpha}[\tau_{ij}]^{\beta}}{\sum_{l \epsilon N_i}[\tau_{il}(t)]^{\alpha}[\tau_{il}]^{\beta}} \quad (8)$$

$\tau_{ij}(t)$, gives the amount of pheromone in t rounds between cities i and j. τ_{ij} , represents the distance between two cities.

$$p_{ij}^{k}(t) = \frac{a_{ij}(t)}{\sum_{l \epsilon N_i^k} a_{il}(t)} \quad (9)$$

Eq. (9) is used to calculate the probability of choosing the road between cities i and j.

$$\tau_{ij}(t) \leftarrow (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t) \quad (10)$$

Eq. (10) the ro value is used to calculate the amount of pheromone between the cities numbered i and j. Fig. 7 shows the flowchart of ant colony optimization.

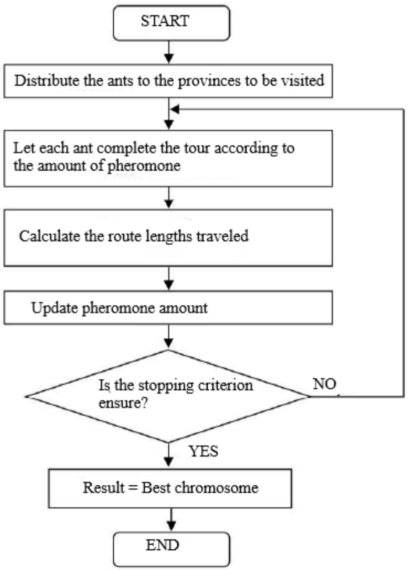

Fig. 7. ACO flow chart

Ant colony algorithm is utilized for settling the optimal size and location of DGs, solution content allotment problems in distribution systems, minimum power loss.

3.2.4. Grey Wolf Optimization

Inspired by the leadership hierarchy and hunting mechanism of gray wolves in nature, the recently developed heuristic has been successfully applied for time to solve economic dispatch problems, feature subset selection, dual network optimal design. Grey wolves follow a strict separation of social layer. This distinction is made as alpha, beta, delta and omega. The way gray wolves hunt consists of following the prey, then surrounding it and finally attacking the prey.

Grey wolves surround the prey during the hunt and its expression is mathematically equivalent.

$$D = \left|\vec{C} \cdot \overrightarrow{X_p}(t) - \vec{X}(t)\right| \quad (11)$$

$$\vec{X}(t+1) = \overrightarrow{X_p}(t) - \vec{A} \cdot \vec{D} \quad (12)$$

t represents the current loop and are the coefficient vectors, the situate vector of prey.

Vectors are computed as:

$$\vec{A} = 2\vec{a} \cdot \vec{r_1} - \vec{a} \quad (13)$$

$$\vec{C} = 2.\vec{r_2} \quad (14)$$

where the components are linearly dropped from 2 to 0 during iterations and are random vectors.

When hunting, alpha usually leads the wolf pack. this is not going to be a good answer in good case space. Therefore, it is accepted that alpha, beta and delta have knowing of the place of prey and wolves. Omega acts according to the direction. The mathematical expression showing the position vector of this agent is given below [45, 46].

$$\overrightarrow{D_\alpha} = \left|\overrightarrow{C_1} \cdot X_a - \vec{X}\right|,\ \overrightarrow{D_\beta} = \left|\overrightarrow{C_2}.X_\beta - \vec{X}\right|,\ \overrightarrow{D_\delta} = \left|\overrightarrow{C_1} \cdot X_\delta - \vec{X}\right| \quad (15)$$

$$\overrightarrow{X_1} = \overrightarrow{X_\alpha} - \overrightarrow{A_1}\overrightarrow{D_\alpha},\ \overrightarrow{X_2} = \overrightarrow{X_\beta} - \overrightarrow{A_2}\overrightarrow{D_\beta},\ \overrightarrow{X_3} = \overrightarrow{X_\delta} - \overrightarrow{A_3}\overrightarrow{D_\delta} \quad (16)$$

Eq. (15) and Eq. (16) refers to the location update for the best search. The final step is reached when you stop moving.

Frequency variation can be used to optimize controller gains and achieve dynamic responses as desired, while gray wolf optimization can be used to keep power variation within nominal values, ensure carbon emissions, and improve power quality. The coefficients of the PID controller can be better controlled by this optimization.

3.2.5. Bat Algoritm (BA)

Bat optimization, a swarm intelligence optimization algorithm, was suggested by Yang in 2010. It simulates the behavior of bats in nature and speeds up their convergence by adjusting the search frequency during the search process. Recently, bat algorithm has started to be preferred in fields such as classification, feature selection, neural networks, data mining. The theory and practice of BA has greatly advanced [36]. The advantage of bat algorithms is that by changing the parameters, the exploit creates an adaptive balance component and can perform global exploration [48]. Bats always fly at a random speed in a location with fixed frequency, variable wavelength and loudness to hunt their prey. The impact height of the bat can vary in different situations. However, Yang thought that it ranked from a positive big number to a minimum fixed number. Adjusting the frequency, loudness and pulse rate in the simulation is required to produce a new solution. (Eq. (17)–(18)) and the obtained solution is tried to be better obtained by comparing it with the previous one depending on how close the optimal solution is by adjusting the loudness and pulse rate, respectively.

$$f_i = f_{min} + (f_{max} - f_{min})\beta \quad (17)$$

$$v_i t = v_i t - 1 + (x_i t - x *) f_i$$

$$x_i t = x_i t - 1 + v_i t \quad (18)$$

From the over equations, (x_i) is wont to replace the bat's position in the check arrange, while (v_i) and (f_i) are used to indicate the velocities and frequency of the impact, respectively. (β) corresponds a vector of random numbers from 0 to 1, (x ∗) represents the best solving ever procured. By determining the upper limit and lower limit of the frequency, the optimization problems are dimensioned. In the first iteration, each bat is allocated an arbitrary frequency number, and the bats are moved to their new location using their new speed. As the bats approach their prey (A_i) decreases while the value of (r_i) increases as shown in the following two equations [49].

$$A_i^t = \alpha A_i^{t-1} \quad (19)$$

$$r_i^t = r_i^0[1 - \exp(-\gamma(t-1))] \quad (20)$$

3.2.6. Whale Optimization Algorithm

WOA is a meta-heuristic developed by Mirjalili and Lewis, this optimization method that mimics the foraging behavior of humpback whales. Like other optimization methods, the optimization process of WOA begins with the initialization of the random population [50]. Humpback whales can acknowledge and hide the site of prey. Since the optimal design's position in space is difficult to know in advance, WOA requests a better solution or near-optimal target hunt Once the best search agent is identified, their positions are updated until they find the best one. This behavior is shown in the following equations;

$$\vec{D} = \left|\vec{C} \cdot \vec{X}^*(t) - \vec{X}(t)\right| \quad (21)$$

$$\vec{X}(t+1) = \vec{X}^*(t) - \vec{A} \cdot \vec{D} \quad (22)$$

Eq. (21) , (22) t represent the current iteration, $\vec{A}$ and $\vec{C}$ represent the coefficient vectors, the place vector of the best solving acquired, X* should be updated when there is a better solution. Expressions of vectors $\vec{A}$ and $\vec{C}$ are calculated as follows [51].

$$\vec{A} = 2\vec{a} \cdot \vec{r} - \vec{a}$$
$$\vec{C} = 2 \cdot \vec{r} \quad (23)$$

WOA has been used to improve the voltage profile of distribution systems, reduce power losses as much as possible and adjust the optimal size of DGs at different power factors [52]

3.2.7. Cuckoo Search Algorithm

The algorithm, inspired by the breeding behaviors of cuckoos, such as brood parasitism, was found by Yang and Deb. In order to reach the best solution in the cuckoo search algorithm, levy flight stages are performed locally and globally. Levy flights are random flying whose direction is random and whose stride lengths are extracted from the Levy issuance. Levy flight can enhance the optimization algorithm's iteration count by up to 4 times compared to random flying [53]. The local levy flight is modeled as follows.

$$x_i^{t+1} = x_i^t + as \otimes H(p_a - \varepsilon) \otimes (x_j^t - x_k^t) \quad (24)$$

In this equation, x_j^t and x_k^t represent two different solution candidates chosen by random permutation, $H(u)$ is the unit step function, ε is the random number from the uniform distribution, and s is the step size. The mathematical expression of the global levy flight is as follows [53,55].

$$x_i^{t+1} = x_i^t + \alpha L(s, \lambda) \quad (25)$$

$$L(s, \lambda) = \frac{\lambda \Gamma(\lambda) \sin\left(\frac{\pi\lambda}{2}\right)}{\pi} \frac{1}{s^{1+\lambda}} (s \gg s_0 > 0) \quad (26)$$

Here, $a > 0$ represents the step size scaling factor and λ the Levy exponent.

CS algorithm, random population selection is done. Then a random solution is chosen for each improvement case. Levy flight is applied to the selected solution, then the solution's position in the population is determined. If the new solution is better than the previous location, the selected location is switched. In this way, a cycle continues until the best result is achieved [54].

4. Conclusion

Studies on the planning of distributed generation in order to meet the energy need, increase reliability and improve power quality have increased in recent years. Optimization methods have been developed for the planning of distributed generation. With the help of probability calculations of optimization methods, various benefits can be achieved through better power quality, voltage stability, cost reduction, reduction of power losses, maximizing distributed generation units, optimal integration and planning of distributed generation. This article reviews research work in the field of DG sizing to improve integration. It was concluded that it would be more accurate to use systems based on mathematical algorithms in distributed generation optimizations. In order to increase the efficiency of renewable energy sources, studies can be carried out on energy storage systems. There has been a growing trend towards optimizing hybrid distributed generation networks that contribute to minimizing polluting emissions, maximizing system reliability and minimizing expected customer downtime costs. The popularity of metaheuristic algorithms can lead to wide use in simple applications, their ability to solve large complex problems with a low computational cost, and in different fields of study. While evolution-based algorithms only store the search space information in the found iteration, swarm-based algorithms can store the search space information throughout the iteration. Particle swarm optimization (PSO), from metaheuristic algorithms based on swarm optimization, does not require algebraic operations to calculate the change of the target function, thus giving better results in terms of positioning. PSO has a simpler structure than other evolutionary techniques. Ant colony optimization has undertaken one of the main tasks in applications such as image processing. Ant colony optimization is more efficient, needs fewer parameters and has strong robustness. It is compatible with other methods and can easily solve complex problems. The grey wolf optimization method is good in that it converges quickly and avoids local minima. Bat algorithm optimization, the dimensions of the problem can determine the upper and lower limits of the frequency. It shows the behavior according to the random frequency number assignment. The bat algorithm cannot go out of the local optimum area, so it does not have the ability to improve. Bat algorithm cannot update changes on complex systems. Therefore, they are not suitable for different applications. Whale optimization algorithm, like PSO, is simple and efficient. Higher convergence speed and accuracy is higher. In this way, this optimization method is more reliable. Cuckoo search algorithm has faster learning rate, low convergence in global optimum, and can maximize the performance of learning strategy to solve complex problems. Unlike other methods, the genetic algorithm does not require the use of auxiliary information. The genetic algorithm iterates starting from the set of points. That way it doesn't get stuck on the local best solution. Genetic algorithm uses probability rules. One of the evolution-based algorithms, genetic algorithm can be used to prevent premature convergence and diversify the herd. The most suitable and most widely used optimization method for the control system has been observed as the particle swarm optimization technique. A hybrid system consisting of a combination of gray wolf optimization and a PID controller can be useful for control systems. Metaheuristic optimization algorithms can easy to transform, overcome local minima, and respond to problems in different domains.

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