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Distribution Network Development Planning in the Presence of Distributed Generation Resources by Lightning Search Algorithm

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Abstract

In recent years, the distribution network has experienced significant growth due to the increasing demand for electric energy. As a result, there is a need to expand the existing distribution network to accommodate more users. Two solutions are proposed for developing the distribution network and supplying the required electrical energy. The first solution involves utilizing scattered production resources near the consumption points. The second solution is about construction of new lines which is a practical method in the distribution network development program. However, due to inadequate system design, significant amounts of electrical energy are wasted. and resulted in substantial financial burdens for energy distribution companies. In this paper, the focus is on planning the development of electrical energy distribution networks. This involves determining the capacity and optimal location of scattered production sources and choosing the best routes for constructing

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new lines within the standard 33-bus distribution network. The methods used for this purpose are particle swarm optimization algorithms (PSO) and lightning search. (LSA). Simulation has been done in three scenarios. In the first scenario, the cost reduction of the network development program has been done by locating and determining the capacity of scattered production sources, and in the second scenario, this has been done by constructing new lines in the network. Finally, in the third scenario, locating and determining the optimal capacity of scattered production resources along with the construction of new feeding routes have been done simultaneously by these two algorithms. The results of the simulations indicate that the most effective method for developing electrical energy distribution networks is to simultaneously utilize distributed generation and construct new lines. In this case, network development will have the lowest cost. On the other hand, the proposed lightning search algorithm has been able to perform better than the particle swarm algorithm in all defined scenarios, and with the development program provided by this algorithm, the lowest cost has been obtained.

1. Introduction

Today, the electricity industry can be considered one of the main foundations of the economy and industry of any country. With the development and growth of technology, industries and population, the amount of electrical energy required increases significantly. Since the beginning of the electricity industry, most of the energy needed by countries comes from the conversion of thermal energy stored in fossil fuels such as coal and natural gas. The generated electrical energy is transported through transmission lines to the place of consumption and then provided to consumers through energy distribution lines, in the meantime, significant amounts of electrical energy are wasted in different ways for various reasons.

Experts have always paid more attention to the production and transmission sectors. Therefore, the problems of production and transmission systems have been solved to a large extent. But due to less attention to distribution networks, this part of the power system has not seen many changes in its structure and operation over the years. The development of distribution networks has always been only according to the needs and less long-term and calculated development plan has been considered for its development. According to other words, distribution network operators decide to expand the distribution network and create new branches in accordance with the load growth and the demand of new consumers. Therefore, to solve this problem, they will decide to strengthen the network and replace some of its components [A1]. With the increase in the use of electrical energy and the need for this energy source, electrical networks are considered one of the most important infrastructures in any country. The purpose of the power system is to provide the electrical energy needed by the electricity customers, with a favorable price and quality. First, electrical energy is produced in power plants. Then the electric energy produced is delivered to the distribution network through the transmission lines. The distribution network is the last link of the electric energy transmission system to the electricity subscribers, and the most important task in the power network, i.e. feeding the consumers, is the responsibility of the distribution network. Planning the development of distribution networks is one of the most important parts of planning the development of power networks. Transmission networks are responsible for the transmission of produced electrical energy, the purpose of which is to find a suitable model for the development of power plants, which, by constructing them, while providing the energy needed by consumers in a reliable manner, the lowest cost is also imposed on the network for supplying loads, and the network also achieve the highest level of stability and losses of transmission lines by power plants are in their optimal conditions. Based on this, in the aforementioned planning, it should be specified that the new power plants with what capacity, at what time and at what place should be built in order to fulfill the above objectives. This planning is usually done for a period of 10 to 20 years. Restructuring and changing the laws of electrical power systems and the establishment of the electricity market in many developed countries have transformed the studies of operation in power systems, and this means that in many studies, the type of view and limitations governing the issue Compared to the past, there has been a serious difference, and the view of the electricity market has dominated them. In the restructured environments of electric systems, electricity distribution companies are always looking for new planning strategies for their covered network with the aim of reducing the current costs of the network and increasing the income from the sale of their electricity, in order to use They can always be responsible for providing the load growth of their covered areas in an economic way, so that they can always provide electricity at a cheap price and high quality to their subscribers, and on the other hand, they can always remain in the competition scene of the electricity market. The presence of many elements in distribution networks, which leads to many decision variables, has made the problem of designing and developing these networks difficult. It has increased the economy, especially in restructured environments, and has caused the designers of distribution networks to turn to more accurate and suitable methods for designing these networks [A2]. The development of distribution networks in order to increase its efficiency is done in different ways and approaches. In this research, distribution network development planning in the presence of scattered production resources with the approach of reducing operating costs is the subject of research. Studies will be conducted on IEEE 33-bus standard system. The proposed objective function is the sum of the energy costs exchanged with the upstream network and the cost of network development, including the cost of constructing lines and installing scattered products in a twenty-year period. To perform optimization, the powerful lightning search algorithm is used for optimization. Accuracy and high speed of convergence are among the unique features of this algorithm, which is suitable for solving the optimization problem in the present research.

2. Effective factors in the design and operation of distribution networks

With the increasing dependence of social life on electric energy, reliability of non-interruption of electricity, continuity of service, good quality, sufficient safety and low cost are among the expectations of electricity subscribers. The price that subscribers pay for electricity consumption is practically determined by the costs of electricity production, transmission and distribution. For almost all subscribers, service continuity and no power outages are very important. Therefore, the proper design and operation of distribution networks (due to the closeness of the distribution system to consumers) has gained tremendous value. Subscribers would like the electricity delivered to them to have complete reliability, but from a technical and economic point of view, this is an unattainable goal. The optimal level of reliability depends on the economic impact of power outages, which is different for different subscribers. According to the conducted studies, commercial and industrial subscribers are more affected by power outages than other subscribers, followed by public, agricultural and domestic subscribers respectively [A3].

After reliability, the second effective factor in the design and operation of distribution networks is economic considerations, in which network losses play an important role, and minimizing losses has always been one of the important design goals. Another factor that determines the quality of electric energy delivered to customers is the actual value of the voltage. If the voltage goes out of the allowed range, the electrical devices will be more or less damaged. High voltages usually occur due to faults in voltage controllers or faults in the network. High voltage drop in distribution networks is usually the main cause of voltage drop from its permissible value. The presence of harmonics and the significant difference of the waveform from the complete sinusoid may cause incorrect operation of electrical devices [A4].

2.1. Structure of distribution networks

Distribution systems are generally radial and deliver electrical power from a source to loads connected to main or sub feeders. According to the voltage level of the system, geographical conditions and concentration or lack of concentration of sufficient load, various types of distribution networks can be used to meet the needs of subscribers. In general, distribution networks can have any type of structure, but in standard mode, three types of general structures can be introduced for distribution networks [A5]:

1- Radial network
2- Circular network
3- Sieve network

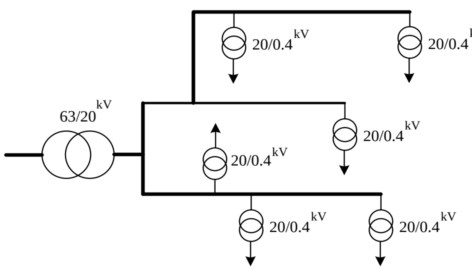

Fig. 1: Radial network structure [A5]

In the radial network, the circuit is drawn from the main bus to the distribution transformers and goes to the end of the feeder. One of the advantages of this system is the simplicity of its shape and the cheap construction of this network. The biggest disadvantage of the radial network is the lack of electricity from the faulty part to the end of the feeder in this type of system, which will increase the cost of unsold energy to subscribers, and subsequently reduce system reliability and consumer dissatisfaction. Today, to solve this problem, maneuvering lines are used to electrify the non-electric part by nearby feeders.
To increase the reliability of electrical energy distribution networks and reduce outages, these systems can be designed as double-feed or circular. In this way, the feeding of the medium pressure feeder after starting from the main bus and after passing through the distribution posts returns to the same bus. In this system, if an error occurs on the network, the damaged part of the network is isolated by using sectioners, and other parts of the network that are affected by the error will be fed from the other path of the feeder. This mechanism is called network recovery in distribution systems. Among the advantages of these networks compared to radial networks, the following can be mentioned:

1- The ring network gives less blackout compared to the radial network.
2- Ring network does not need to use maneuvering lines.
3- In this type of networks, there is no concern about the insulation failure of the lines.

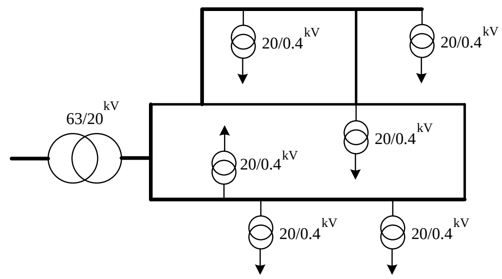

Fig. 2: Ring network structure [A5]

3. Distribution network development program

With the increase in the number of subscribers in electrical energy distribution systems, new feeders must be built, which are not economically viable, or the existing network must be developed. In the development of the distribution network, various methods are used, among which the use of active resources and its connection to the electric energy distribution networks, as well as the construction of new lines along the feeder, as practical methods in the development program. They are distribution network [A6], which is followed by the introduction of each of them.

3.1. Distributed Generation resources

The traditional structure of electricity networks has always been based on the absence of active sources of electric energy production in distribution networks. With the increase in the installed capacity of these production sources and due to the existence of different technologies in the construction and use of these production sources, it is very important to study the effects of such sources when they are connected and operate in parallel with electric networks. There are two theories about the presence of distributed production in the distribution network. Some believe that DGs should provide all the power needed by the distribution network, so these networks do not need transmission lines and huge power plants. Others are of the opinion that distributed generation should be responsible for part of the local power requirement. Depending on the characteristics of the network and the type of resources, distributed generation can have positive or negative results.

Scattered production sources with the production of electrical energy at the installation site will reduce the amount of energy production in distant power plants, and as a result, the resulting transmission costs and also the amount of line losses will be reduced. It should be kept in mind that the use of these resources involves costs, and these costs include investment and installation, operation and maintenance. The existence of such costs leads to the fact that the use of these resources has limitations. In other words, it is not possible to install a distributed generation source in a distribution network as expected. Perhaps the installation of distributed generation sources without restrictions will make the losses in the power network decrease dramatically; But due to the high installation and investment costs and other costs, it is not possible to implement this. The location of scattered production resources, their capacity and production rate should be determined in a suitable way to achieve the following [A7].

- Sufficiency of energy production: to meet the needs of customers and network loads.
- Reduction of losses: Minimize line losses.
- Optimum quality of electricity: the quality of electricity for subscribers should be at a suitable level.

The use of distributed production resources in the power grid has many advantages. These benefits can be divided into economic and non-economic categories. In the following, these benefits will be described and discussed.

3.2. Economic benefits

The most important economic advantage of distributed generation units is the reduction of electric energy production costs. This cost reduction can be seen in the following cases [A7]:

1) Reducing the amount of losses in the distribution networks and as a result reducing the costs caused by it;
2) The reduction of investment for the development of the infrastructure of the distribution network is a result of the reduction of load density without the need to change the system and provide energy for remote areas;
3) Reducing current harmonics and thus avoiding extensive filtering and eliminating the resulting exorbitant costs;
4) Using cheaper fuels as well as reducing heat losses in the process of producing electrical energy;
5) Reducing the project completion time as well as low-risk investment due to small-scale manufacturing.

4. Objective functions and constraints

In order to plan the development of the network and the construction of new lines, as well as the installation of scattered products in the studied distribution network using optimization algorithms, it is necessary to select a suitable objective function. In this thesis, the cost has been chosen as the objective function, which is calculated in the form of equation (1) [A8]:

$$Cost = \sum_{i=1}^{N_B} Cost_{Branch}(i) + \sum_{i=1}^{N_{Cap}} Cost_{DG}(i) + Cost_{Loss} \quad (1)$$

In relation (1), the cost of building a new line is considered, which is calculated as relation (2):

$$Cost_{Branch}(i) = L(i).\pi_B \quad (2)$$

In relation (2), the length of the line is i and the cost of each kilometer of line construction is This cost is related to the cost of initial investment and its construction. In relation (1), the cost of production is dispersed, which includes the cost of the initial investment and the cost of its repairs. Because the horizon of the considered studies was equal to the lifetime of scattered production and equal to 20 years, the replacement cost was not considered in this regard.

$$Cost_{DG} = C_{Invest} + C_{main} \quad (3)$$

In the above relation, the initial investment cost, repair and maintenance cost, which changes annually due to the inflation of costs. The initial investment and maintenance costs are calculated by the relationships (4) and (5) [A8]:

$$C_{main} = C_{main0} \times P_{nom}(i) \times (1 + \frac{(1+r)}{(1+i)} + \frac{(1+r)^2}{(1+i)^2} + \frac{(1+r)^3}{(1+i)^3} + \frac{(1+r)^4}{(1+i)^4}) \quad (4)$$

$$Cost_{Invest}(i) = P_{nom}(i) \times \pi_{DG} \quad (5)$$

In relation (4), *r* and *i* are the inflation rate and interest rate respectively, Cmain0 is the maintenance cost in the first year per kilowatt of installed distributed generation and P_{nom} is the nominal capacity of distributed generation. In relation (5) the initial capital cost required to purchase each kilowatt of production is scattered. Finally, the cost of losses is equal to the amount of wasted energy in the total cost of each kilowatt of production power [A8].

$$Cost_{Loss} = P_{Loss} \cdot \pi_{grid} (1 + \frac{(1+r)}{(1+i)} + \frac{(1+r)^2}{(1+i)^2} + \frac{(1+r)^3}{(1+i)^3} + \frac{(1+r)^4}{(1+i)^4}) \quad (6)$$

In relation (4), the price of electricity in the first year of the project and Ploss is the active loss of the system, which is calculated by relation (6).

$$P_{loss} = \sum_{i=1}^{N_{branch}} RI^2 \quad (7)$$

In the above relationship, R_i and I_i are the resistance and current passing through the i-th branch and N_{branch} are the number of branches, respectively. The connection of scattered sources of production and the construction of lines in the existing network should be done in such a way that the normal operation of the network is not jeopardized. This means that all the requirements for the correct operation of the network are met and the response to the load is done well. As a result, this issue creates limitations, some of which are mentioned below [A8]:

Load distribution restrictions: The following two equations as load distribution restrictions must be maintained in all buses (except for slack buses). There should always be a balance between production and consumption of resources.

$$P_{gi} - P_{di} - P_{loss} = 0 \quad (8)$$

$$Q_{gi} - Q_{di} - Q_{loss} = 0 \quad (9)$$

that in relations (8) and (9), P_{gi} and P_{di} are the active power produced and consumed in the i-th bus, Q_{gi} and Q_{di} are the reactive power produced and consumed in the i-th bus, as well as P_{loss} and Q_{loss}, active and reactive losses, respectively are Bus voltage limit: The voltage of all buses must not exceed the upper and lower limits of the network.

$$|V_i^{min}| \le |V_i| \le |V_i^{max}| \quad (10)$$

In the relation (13) and the upper and lower limits of the allowed voltage, and the voltage of each bus must be between 0.95 and 1.05 per units.

The limitation of the maximum current passing through the lines: The power transmission capacity of the lines is limited. Therefore, the current passing through the lines should be such that it does not exceed the maximum thermal capacity of the lines in the network.

$$|I_{ij}| \le |I_{ij}^{max}| \quad (11)$$

In relation (13), the maximum allowed current passing through the line between bus i and j is limitation of the active production power of scattered products: The active production power of scattered production sources must be within the allowed range. These limitations can also be caused by technical or economic limitations of scattered production.

$$P_{DGi}^{min} \le P_{DGi} \le P_{DGi}^{max} \quad (12)$$

In the above relationship, the active power produced is DG.

Limitation of productive reactive power of scattered products: Productive reactive power must be in the following range.

$$Q_{DGi}^{min} \le Q_{DGi} \le Q_{DGi}^{max} \quad (13)$$

In relation (13), the reactive power produced is DG.

Limitation of the power factor of scattered productions: The power factor of the units must be in the range between the minimum and maximum value.

$$PF_{DGi}^{min} \le PF_{DGi} \le PF_{DGi}^{max} \quad (14)$$

In this regard, the operating power factor is DG. The maximum and minimum power factor of scattered production units were considered equal to 0.6 and 0.9.

Limitation of the diffusion coefficient of distributed generation: The total capacity of distributed generation units in the network is a coefficient of the total load in the network, which is referred to as the diffusion coefficient. This value should not exceed the allowed penetration coefficient for distributed generation units [A9].

$$\rho_t \leq \rho_t^{std} \tag{15}$$

In relation (15) the allowed penetration coefficient for installing Tully units.

5. The studied power system

In order to study the distribution network development program, IEEE 33-bus standard system has been chosen as a sample feeder to perform simulations. This system has been used by many researchers in different articles. The aforementioned feeder, like most electrical energy distribution systems, has a radial structure that is connected to the national network. In Figs. 1,2, and 3, the desired network topology is displayed. The studied system has 33 nodes, 32 available lines. Lines 33 to 37 are considered as candidate routes for the development of the distribution network, which are shown with dashed lines.

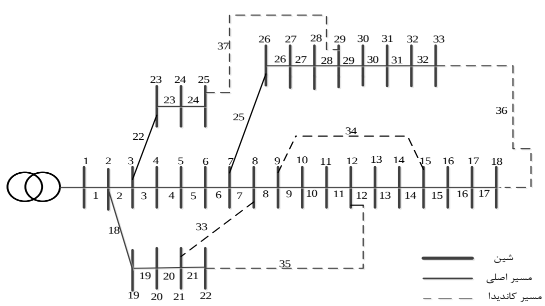

Fig. 3: One-line diagram of the 33-bus network with the application of maneuver keys [A10]

The amount of system losses before changing the network configuration and installing distributed generation sources is calculated as 211 kW. Fig. 4 shows the ohmic losses of the lines in the form of bar graphs. The maximum ohmic loss of the lines in the line between the 2nd and 3rd busbars is equal to 51 kW.

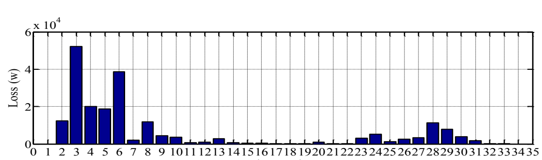

Fig. 4: Losses of lines in the studied network before changing the layout of the network and installing distributed production sources [A10]

On the other hand, after the development of the studied network, the voltage of all buses should remain within the permissible range. For this purpose, in Fig. 5, the voltage range of the busbars before the development plan is displayed. The lowest voltage range for bus is 18 and equal to 0.9 per unit.

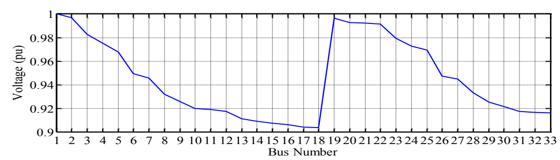

Fig. 5: voltage profile in the studied network [A10]

6. Introducing Lightning Search Algorithm

Lightning is a transient electric discharge with high current. This electric discharge occurs when a region of the atmosphere has a high electric charge, and the resulting field causes the electric breakdown of the air. Discharge between clouds or between clouds and the ground begins following the increase in the intensity of the electric field and the ionization of a narrow and uncertain path from the air in the distance between the two electric poles. The moment of occurrence of lightning depends on the amount of charge increase and the intensity of the electric field in the distance between the clouds or between the clouds and the ground. Every lightning that hits the ground starts with a weak initial discharge which is a progressive branch and spreads from the cloud to the ground, followed by a return path that is associated with high intensity, and spreads from the ground to the cloud. In fact, the primary discharge from the cloud to the ground that occurs before the return path is called the phase progressive branch. According to the opinion of many researchers, a phase progressive branch occurs with an electric breakdown between the N and P charges in the cloud, and this breakdown moves the electric charges that were previously attached to the ice and small water particles. At this time, with the accumulation of negative charges in the cloud, an electric field is created, which moves towards the ground in the form of a column.

The lightning search algorithm is a meta-optimization algorithm modeled on the natural phenomenon of lightning in 2015. This algorithm uses the progressive branch propagation mechanism in lightning. In the lightning algorithm, the faster particles that are called projectiles are considered as the advancing branch in the form of a binary tree search structure. The progressive branches formed by the projectiles determine the initial size of the population. In fact, projectiles suggest random solutions for problem solving by lightning search algorithm. A projectile loses its kinetic energy through movement in the atmosphere and by stretching collisions with air molecules. The velocity of the projectile (v_p) and its kinetic energy (E_p) are shown as below [A11].

$$v_p = \left[1-(1/\sqrt{1-(v_0/c)^2}-sF_i/mc^2)^{-2}\right]^{-0.5} \quad (16)$$

$$E_p = \left(\left(1/\sqrt{1-(v_p/c)^2}\right)-1\right)mc^2 \quad (17)$$

In the above relationships, v_0 the initial speed of the projectile, s is the length of the path, F_i is the constant rate of ionization, m is the mass of the projectile, and c is the speed of light. The speed and kinetic energy depend on the position of the moving branch and the mass of the projectile. Therefore, when the mass is small or the distance traveled is long, then the energy projectile will have less potential for ionization. In addition, the power of discovery and the capacity of using this algorithm can be controlled by the relative energies of the advancing branches. Due to the formation of a projectile that exits in a random path during lightning, the tip of the arrow is formed in the initial stage. Therefore, it can be modeled as a random number that uses the standard uniform probability distribution on the search space. The probability density function is defined as follows [A11].

$$f(x^T) = \begin{cases} 1/b-a & a \le x^T \le b \\ 0 & x^T < a \,\|\, x^T > b \end{cases} \quad (18)$$

In this relation, x^T is a random number that makes the initial energy of the forward branch, a and b form the upper and lower limits of the search space, respectively. For a population consisting of N progressive branches, N random particles are needed. When the forward branches have evolved, they should replace their positions by ionizing the sections adjacent to the best answer in the next step. The location of the space projectiles in the next step can be considered almost as a random number generated from the exponential distribution.

$$f(x^S) = \begin{cases} \frac{1}{\mu} e^{\frac{-x^S}{\mu}} & x^S \ge 0 \\ 0 & x^S < 0 \end{cases} \quad (19)$$

μ is the formation coefficient that can control the loca tion of the projectile. The location of the space projec tile can be calculated from the following equation:

$$P^S_{i\_new} = P^S_i \pm ExpRand(\mu_i) \quad (20)$$

In the above relationship, *ExpRand*() is an exponential random number, if it is negative, then the generated random number must be negative. Because the relation (19) only takes positive values. However, the new location does not guarantee the propagation of the leading branch or the formation of the channel unless the energy of the projectile is higher than the leading branch to find a good solution. If the right answer is found in the next step, the corresponding progressive branch will be moved to the new location and will be updated. Otherwise, the values will remain constant until the next step. If extended, the most extended leader will become the guided projectile. The projectiles related to the advancing branch that have reached the closest place to the earth will not have enough potential to ionize the large parts in front of the tip. Therefore, the projectile is a random number from the normal probability distribution density function expressed in equation (21); It becomes a model.

$$f(x^L) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x^L-\mu)^2}{2\sigma^2}} \quad (21)$$

The standard deviation for the guided projectile decreases exponentially until it reaches the ground. In other words, it finds the best solution. Therefore, the new location is displayed in the form of the following relationship:

$$P^L_{i\_new} = P^L_i \pm D^L \times NormRand(\mu_L, \sigma_L) \quad (22)$$

In the above relation, *NormRand*() is a random number generated by the normal probability density function.

The new location does not guarantee propagation of the forward branch unless there is more energy to expand the solution. If it provides a good solution in the next step, the PL will be updated.

7. Simulation and analysis of results

Distribution system development planning can be done at once or in several stages. Since load points may be added to the system over several periods of time, it is more economical to install the equipment needed to supply the load of these points as much as possible simultaneously with the addition of these points to the system in order to avoid premature investment. For this purpose, it is possible to plan the expansion of the distribution system and install the required equipment according to the needs of the network, according to the time intervals of adding loads to the system. For this purpose, expansion planning is done in a dynamic and multi-stage manner, taking into account the load growth and the addition of load points. In this chapter of the thesis, the results obtained from the simulations in the MATLAB software environment have been investigated. A handheld computer with an Intel® Core TM i5-6200U 2.3 GHz Turbo Boost up to 2.8 GHz processor and 8 GB DDR4 access memory (RAM) was used for simulations. Studies have been carried out on two standard 33-bus distribution systems in the form of three scenarios.

- First scenario: network development planning with distributed production installation.
- The second scenario: planning the development of the network by building new lines.

For the network development program, two lightning search and particle swarm algorithms have been used, and the parameters of these two algorithms are given in Table 1. It has been tried to select the parameters of the two algorithms in such a way that they have the best performance so that a fair decision can be made about their performance.

Table 1: Parameters of optimization algorithms

PSO	Population	Iteration	C1=C2	V_{min}	V_{max}	W
	100	35	2	0/4	0/9	0/7
LSA	Population	Iteration	γ	α	β	
	100	35	0/6	0/7	0/5	

Before carrying out the development plan of the distribution network and in the absence of production resources and no construction of new lines, assuming the cost of each kilowatt of electrical energy produced in the first year equals 0.024 dollars, the cost of losses in this feeder equals 221.8 thousand dollars will be. Also, the fixed and variable cost of each megawatt of distributed production power is equal to 86 thousand dollars. Inflation and incentive rates are 9% and 4%, respectively. In the process of optimization, it should be noted that after the development of the studied distribution network, two conditions should be considered. The first condition is related to the radiality of the network and the second condition is related to the non-creation of islands in the network.

7.1. The first scenario (network development with the installation of Distributed Generation)

In the first scenario, the development planning of the studied 33-bus distribution system is discussed by locating and determining the capacity of scattered production resources by lightning search and particle swarm algorithms. It is assumed that there is only the possibility of installing two scattered productions along the said feeder. In Fig. 6, the changes of the objective function in different iterations of PSO and LSA algorithms are shown.

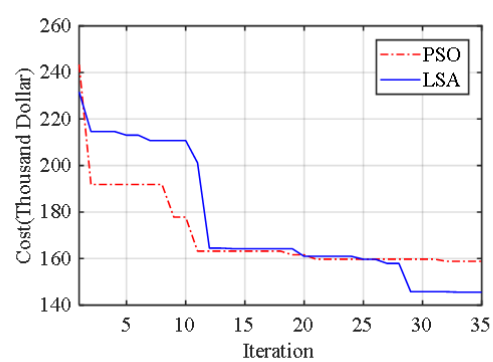

Fig. 6: The objective function change curve in the first scenario

As shown in Fig. 6, the LSA algorithm has converged to $145.58 thousand after 29 iterations, while the value of the objective function for the PSO algorithm after 32 iterations is $158.86 thousand. The speed and the final value of the LSA algorithm is less than the PSO algorithm, which indicates the better performance of this algorithm in the first scenario. The time for optimization in the first scenario by LSA algorithm is approximately 57 seconds and in the case of optimization by PSO algorithm, it is approximately 69 seconds. In the following, the values obtained from the optimization are given in Table 2.

According to the optimization results, after locating and determining the optimal production capacity by the PSO algorithm in the studied feeder, distributed productions with a capacity of 785 and 565 kilowatts are proposed to be installed in 8 and 30 buses, respectively. While using the LSA algorithm, Bus 7 with an active power capacity of 670 kw and Bus 28 with a capacity of 650 kw have been selected to achieve the minimum cost of network development. The amount of loss and cost for the PSO algorithm is equal to 1.93 kw and 158.86 thousand dollars, respectively, and for the LSA algorithm, the amount of loss is equal to 82.6 kw and 145.58 thousand dollars, and the amount of loss and cost for the algorithm LSA has been obtained less than PSO algorithm, which shows the accurate and correct performance of this algorithm in minimizing both indicators. In the following Fig. 7 the power losses of all lines after the placement and determination of the capacity of distributed production sources are given.

Table 2: simulation results in the first scenario

	DG 1		DG 2		LOSSES (KW)	Loss reduction percentage	COST
	BUS	capacity	BUS	capacity			
Basic conditions	-	-	-	-	211	0	221.8
PSO	8	785	30	565	93.1	55.87	158.86
LSA	7	670	28	650	82.6	60.85	145.58

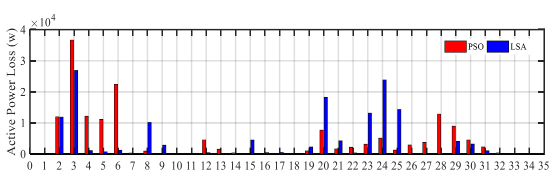

Fig. 7: Line losses amount if distributed production is used

In Fig. 7, the red bars show the line losses when optimized by the PSO algorithm and the blue bars show the ohmic losses of the lines related to the LSA algorithm. As shown in this figure, the line losses For the LSA algorithm, in most lines, it is lower than the PSO algorithm. In order to evaluate the performance of these two algorithms in the first scenario, the values of losses and costs in this scenario are displayed in the form of a bar chart in Fig. 8.

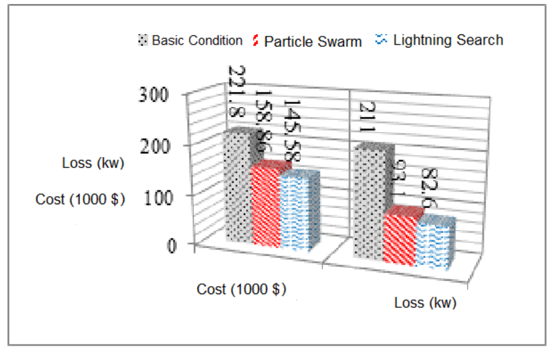

Fig. 8: Costs and losses of the studied system in presented distributed generation used two algorithms

As shown in Fig. 8, after installing distributed production in the studied system, the losses have been reduced by more than 50%. The total cost of the system in case of locating and determining the capacity of scattered products in the studied feeder by the PSO algorithm is equal to 62.94 thousand dollars and about 28.4%, while if the lightning search algorithm is used as an optimization method, the total cost of the system is 76.22 thousand dollars, that is, about 34.4% is reduced.

7.2. The second scenario (developing the network with the construction of a new feeding route)

In this scenario, the issue of reducing the cost of developing the distribution network in the 33-bus feeder by constructing new feeding routes is the issue. For this purpose, this time, the algorithms should choose new paths for implementation, which, by constructing them, according to the radial condition, the losses will be minimized and the cost will be optimal. Therefore, according to the amount of feeder load, routes should be selected whose length is not too long, which will increase the cost. Fig. 9 shows the convergence curve of the objective function in different iterations for two LSA and PSO algorithms.

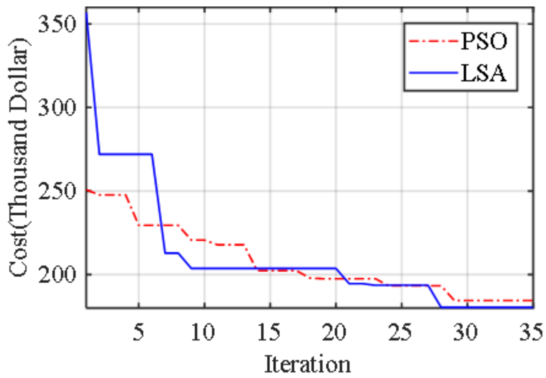

Fig. 9: Convergence of algorithms in the second scenario

The lightning search algorithm has converged to its final value of 180.39 thousand dollars after 28 iterations, while the particle assembly algorithm has reached the value of 184.53 thousand dollars after 29 iterations. The simulation execution time for two LSA and PSO algorithms in this scenario is approximately 51 seconds and 63 seconds. The selected routes for the implementation of the new line, the amount of losses, the percentage of loss reduction and the cost of the system after optimization, are given in Table 3.

Table 3: Optimization results in the second scenario

	Suggested routes for installing new lines	Losses (kw)	Loss reduction percentage	Cost
Basic conditions	-	211	0	221.8
PSO	33 - 35 - 36	134.7	36.16	184.53
LSA	33 - 34 - 37	141.4	35.98	180.39

According to the optimization results, in case of optimization by PSO algorithm, lines 33, 35 and 36 (according to Fig. 9 have been proposed for implementation and installation, and lines 8, 10 and 32 of the circuit They go out. If LSA algorithm is used, lines 33, 34 and 37 are proposed for installing new lines and lines 7, 10 and 28 are removed from the circuit to minimize the cost function. The amount of losses of the distribution system in case of using PSO and LSA algorithms has been obtained as 134.7 and 141.4 kilowatts, respectively. The amount of loss in this scenario for the LSA algorithm is higher than the PSO algorithm, while the cost of the lightning search algorithm is lower than the particle assembly. The amount of losses will be reduced by 36.16% in case of construction of branches 33, 35 and 36, while if lines 33, 34 and 37 are used, the amount of losses will be reduced by 33%. The cost of the PSO algorithm in the second scenario is equal to 184.53 thousand dollars, which is about 37.2 thousand dollars more profitable than the situation in which the new feeding route is not implemented. In the same conditions, the cost of the LSA algorithm was estimated to be 180.39 thousand dollars, and the cost reduction compared to the basic conditions for this algorithm was approximately 41.4 thousand dollars. Next, the power losses of all lines after the installation of new lines are shown in Fig. 10.

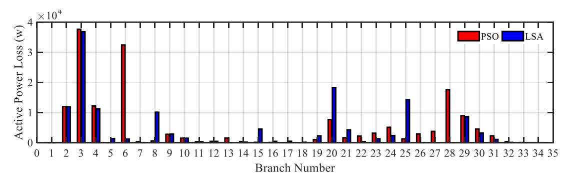

Fig.10: The amount of line losses after the construction of the lines

As shown in Fig. 10, the amount of line losses after the implementation of new lines has decreased significantly, which has caused the cost of losses in the feeder to decrease. Next, in Fig. 11, the results obtained from the optimization in the second scenario are compared with each other.

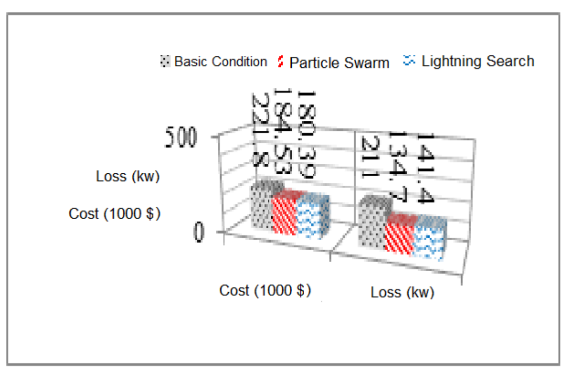

Fig. 11: Comparison of optimization results in the second scenario

In Fig. 4, the losses and costs are displayed as bar graphs. According to the values obtained in the second scenario, it can be concluded that although the amount of system losses in the case of implementing the new routes selected by the LSA algorithm was greater, it was able to keep the cost constant in a lower amount than the PSO algorithm.

8. Conclusion

In the last few decades, the growth trend of distribution networks in developing countries has increased significantly due to the increase in the demand for electric energy by subscribers. For this purpose, it is necessary to develop the existing distribution network. There are two solutions to develop the distribution network and supply energy needed by most subscribers. The use of distributed production and the supply of electrical energy to subscribers near the place of consumption, as well as the construction of new lines, are among the basic solutions for the development of the distribution network. However, due to the lack of proper design of these systems, significant amounts of electrical energy are wasted in them. Energy losses in power grids impose huge sums on power companies. In addition to the loss of income, the cost of losses also includes investment costs for creating new facilities and blackout losses. The limitation of energy resources and the high cost of energy transmission to customers have encouraged engineers, designers and researchers of the power distribution industry to increase efficiency and reduce network losses in the last decade. In other words, a further reduction in losses leads to an increase in capital. Therefore, reducing losses is considered an economic activity in line with the distribution network development program, and it causes a reduction in the cost of installing additional equipment in the network, the rate of energy and power loss, the rate of carbon dioxide emission, and other economic parameters. About 75% of power grid losses occur in the distribution sector, so losses in distribution systems are of great importance. From particle swarm algorithms (PSO) and lightning search (LSA) in order to plan the development of electrical energy distribution networks by determining the capacity and optimal location of scattered production sources and choosing optimal routes for building new lines in the standard 33-bus distribution network. Used. Simulation has been done in three scenarios. In the first scenario, the cost reduction of the network development program has been done by locating and determining the capacity of scattered production resources, and in the second scenario, this has been done by constructing new lines in the network. Finally, in the third scenario, locating and determining the optimal capacity of scattered production resources along with the construction of new feeding routes have been done simultaneously by these two algorithms. After optimization in the first scenario, the losses and costs for the PSO algorithm are equal to 93.1 kW and 158.86 thousand dollars, respectively, and for the LSA algorithm, the loss values are 82.6 kilowatts and 145.58 thousand dollars. It has been found that the loss and cost values for the LSA algorithm are lower than the PSO algorithm, which shows the accurate and correct performance of this algorithm in minimizing both indicators. The total cost for the PSO algorithm has been reduced by 28.4% and for the lightning search algorithm by 34.4% compared to the basic conditions. The studies of this scenario indicate that by installing distributed generation in the studied system, losses will be reduced by more than 50%.

In the second scenario, the issue of reducing the cost of the distribution network development program has been done by building new supply lines. In this scenario, it was assumed that it is possible to build a maximum of three routes in the distribution network. In this situation, after optimization, the amount of losses of the distribution system in case of using PSO and LSA algorithms is equal to 134.7 and 141.4 kW, respectively. Although the amount of loss in this scenario is higher for the LSA algorithm than the PSO algorithm, but the cost for the lightning search algorithm is lower than that of the particle assembly. The cost of the PSO algorithm in the second scenario is equal to 184.53 thousand dollars, which is about 32.7 thousand dollars more profitable than the situation in which the construction of the line is not done. In the same conditions, the cost of the LSA algorithm was estimated to be 180.39 thousand dollars, and the cost reduction compared to the basic conditions for this algorithm was approximately 41.4 thousand dollars.

References

[A1] Bhargava, V., Sinha, S. K., & Dave, M. P., Voltage Stability Enhancement of Primary Distribution System by Optimal DG Placement, Applications of Artificial Intelligence Techniques in Engineering, 1, 2019, 65-78.

[A2] Kaveh, M. R., Hooshmand, R. A., & Madani, S. M., Simultaneous optimization of re-phasing, reconfiguration and DG placement in distribution networks using BF-SD algorithm, Applied Soft Computing, 62, 2018, 1044-1055.

[A3] Sultana, U., Khairuddin, A. B., Sultana, B., Rasheed, N., Qazi, S. H., & Malik, N. R., Placement and sizing of multiple distributed generation and battery swapping stations using grasshopper optimizer algorithm, Energy, 165, 2018, 408-421.

[A4] Syahputra, R., Soesanti, I., & Ashari, M., Performance Enhancement of Distribution Network with DG Integration Using Modified PSO Algorithm, Journal of Electrical Systems, 12(1), 2016, 1-19.

[A5] Kashyap, M., Mittal, A., & Kansal, S., Optimal Placement of Distributed Generation Using Genetic Algorithm Approach, In Proceeding of the Second International Conference on Microelectronics, Computing & Communication Systems, 17, 2019, 587-597.

[A6] Tooryan, F., & Collins, E. R. “Optimum size and placement of distributed generators in microgrid based on reliability concept”. IEEE Power and Energy Conference at Illinois (PECI), 1, 2018, 1-6.

[A7] Gkaidatzis, P. A., Bouhouras, A. S., Sgouras, K. I., Doukas, D. I., Christoforidis, G. C., & Labridis, D. P., Efficient RES Penetration under Optimal Distributed Generation Placement Approach, Energies, 12(7), 2019, 1250.

[A8] Pereira S, Ferreira P, Vaz AIF, Generation expansion planning with high share of renewables of variable output, Appl Energy, 190, 2017, 1275–1288.

[A9] Basso TS, DeBlasio R., IEEE 1547 series of standards: interconnection issues, IEEE Transactions on Power Electronics, 19(5), 2004, 1159-1162.

[A10] Canizes B, Soares J, Lezama F, Silva C., Vale Z., Corchado, j.M., Optimal expansion planning considering storage investment and seasonal effect of demand and renewable generation, Renewable Energy, 138, 2019, 937-954.

[A11] Shareef H, Ibrahim AA, Mutlag AH., Lightning search algorithm, Applied Soft Computing, 36, 2015, 315-33.