

Optimal Selection of Conductors in Ghaleganj Radial Distribution Systems

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Abstract

Selection of the best type and most suitable size of conductors is essential for designing and optimizing the distribution network. In this paper, an effective method has been proposed for proper selection and incorporation of conductors in the feed part of a radial electricity distribution network considering the depreciation effect of conductors. Increasing the usability of the electric energy of the power grid for the subscribers has been considered per load increment regarding the development of the country. Optimal selection and reconstruction of conductors in the power distribution radio network have been performed through a smart method for minimizing the costs related to annual losses and investment for renovation of lines by imperialist competitive algorithm (ICA) to improve the productivity of the power distribution network. Backward/forward sweep load flow method has been used to solve the load flow problem in the power distribution networks. The mentioned optimization method has been tested on DAZ feeder in Ghaleganj town as test.

KEYWORDS: optimal reconstruction, conductors, imperialist competitive algorithm, power distribution network, depreciation, loss reduction.

I. INTRODUCTION

Power distribution networks are among the principal parts of supplying electric energy. The optimal design of such networks is one of the major objectives of researchers and experts in the power industry. To supply the loads constantly with a proper quality, in the transmission and distribution of energy, the network should be tested to check how it faces the limitations and constraints. The design of electric networks has two aspects: mechanical and electrical. The organs of industrial communities need electric currents just the way the cells of an organ need blood. The today's life can no longer be imagined without an extensive power network which feeds large and small industrial, residential, and other complexes through its various branches. With a cursory look at the increase in the number of subscribers of the ministry of power and the increase in the electric energy generation capacity, it can be deduced that our society is no exception to the above issue in line with industrialization. One of the major problems regarding operation of distribution networks is the lifetime of conductors and the gradual decline in their useful life. The conductors of transmission and power

distribution lines, which are among the most important parts of the power system, are largely responsible for transmitting and distributing energy across vast areas of consumption regions and for the connection of the different parts of the system. Thus, investigating the effects of depreciation along the lifetime of conductors and providing suitable conditions for the design, fabrication, and operation are crucial. Note that depreciation is an indispensable part of any object in the material world, and the devices and parts used in any network are no exception to this rule. Due to progressive attempts for mitigating energy degradation, in recent years numerous papers have been published on optimal distribution design. Meanwhile, in all of these cases, special problems such as losses of network and selection of the suitable size of conductors warrant investigations [1]. Some papers have also been published on selection of proper conductors for distribution networks. Overall, all of them are based on the fact that costs diminish through optimization of the conductor [2]. Some other researchers have examined the costs resulting from optimization of the type of networks considering the technical constraints of the network. The



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proposed method can be a useful design for planning on radial distribution networks. Reduction of R.I2 losses, improvement in the voltage profile as well as thermal capacity of the lines are among the characteristics of this method [4, 6]. This paper has dealt with selection as well as suitable and optimal incorporation of conductors in sections of radial power distribution network considering the depreciation effect of conductors using a novel method through imperialist competitive algorithm (ICA). Increased usability for subscribers to utilize the power network electricity per increment in the load has been considered in line with the development of the country. Optimal selection and reconstruction of conductors in the radial power distribution network has been performed through a smart method for minimizing the costs related to annual losses and investment for renovating the lines in order to improve the productivity of the power distribution network.

II. LOAD DISTRIBUTION METHOD

In evaluating power distribution networks, the issue of changes in the major elements and structure of the network is important in a wide range of different states for calculations related to the network load distribution.

Figures Load Distribution through Backward/Forward Sweep Method

It is known that to assess the performance of a power distribution network and to test the effectiveness of possible changes on the system in the network planning stage, the load distribution analysis should be performed on the distribution network [7, 9]. Load distribution studies are typically used for determining the following points:

- Proper distribution of active power as well as reactive power in the network branches;
- Investigating whether different parts have become overloaded or not;
- Examining the effects of changes and addition of components on the studied system;
- Inspecting the effects of losses across different parts of the network under critical conditions;
- Analyzing and determining the optimal load receiving conditions of the system;
- Optimizing the losses of the system.

One of the simplest and most useful methods of load distribution in radial distribution networks is the backward/forward sweep method. Notably it has a great convergence and a very high convergence rate.

The backward/forward sweep method algorithm is as follows:

- Firstly, the initial voltage of all buses is chosen as 1 pu.
- When the loads are known, from the endmost buss, the current of every line is calculated by the following relation:

$$S_n = V_n I_n^* \Rightarrow I_n = \frac{S_n^*}{V_n^*} = \frac{P_n - jQ_n}{V_n^*} \quad (1)$$

Note that since in the model, the load of the active and reactive powers is voltage dependent and in each iteration, a

new voltage is calculated, the load power and load current should be calculated in each iteration.

- When the current of each line is known, using KVL relation, beginning from the first bus, the new voltage of each bus is calculated.

$$V_{n+1} = V_n - Z_n I_{Ln} \quad (2)$$

- Again, by knowing the new voltages, the current of each line is calculated from the endmost bus.

- This continues until the maximum difference between the total voltages of buses exceeds the value of accuracy given. The flowchart of the load distribution program is as Fig. 1.

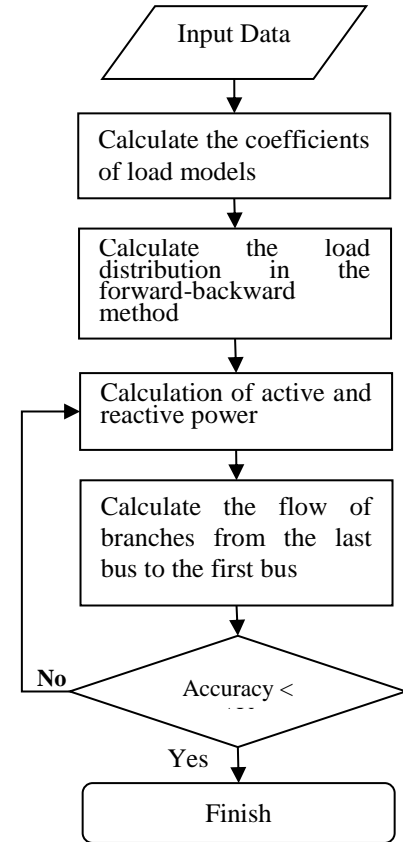


Fig. 1: The flowchart of the load distribution program

III. PROBLEM FORMULATION

A. Objective function

The objective function of the optimization problem is optimal selection of conductors for each branch of the power distribution systems through minimizing the total costs of investment, electric energy losses of the network, and reliability within the permissible range.

$$\text{Min } f(i, c) = w_1 \times CE(i, c) + w_2 \times DCI(i, c) \quad (3)$$

Where, f represents the total costs of energy losses (CE) of investment costs (DCI): i is the system branches, c shows the type of system conductors, n denotes the total number of buses of the network.

$$V_{\min} \leq |V_i| \leq V_{\max} \quad i = 1, 2, \dots, n \quad (4)$$

Where, V_i is the voltage of each bus, V_{\min} is the minimum voltage and V_{\max} is the maximum voltage.

$$CE(i, c) = PL(i, c) \times \{KP + KE \times T\} \quad (5)$$

$$DCI(i, c) = LSF \times A(c) \times \{Cc + Li\} \quad (6)$$

Where, KP is the annual demand cost of subscribers resulting from power losses (Toman/kW); KE shows the annual demand cost of subscribers resulting from energy losses (Toman/kWh); Cc denotes the type of conductor in each section; Li is the length of each section; LSF denotes the coefficient of losses; T represents the time period in terms of h. The losses where the rate of energy losses of the system results from peak power losses within a certain period of time. The LSF is equal to:

$$LSF = 0.84 \times LF^2 + 0.16 \times LF \quad (7)$$

B. FITNESS FUNCTION

In evaluating the fitness function, the value of the objective function of each state is examined in the algorithm process for finding the best solution by the colonial selection algorithm. To enhance the accuracy of the algorithm, we will have:

$$F = \frac{1}{1 + f(c, i)} \quad (8)$$

IV. IMPERIALIST COMPETITIVE ALGORITHM

Imperialist competitive algorithm enjoys a high optimization ability in relation to different optimization algorithms as well as suitable convergence speed [11]. Most of the previously presented optimization methods are computational simulation of natural processes, because of being tangible, as well as the simple formulation and understanding the evolution of these processes. In contrast, in presenting optimization algorithms, in spite of attention to biological evolution of the human and other creatures (genetic algorithms, etc.), the social and historical evolution as the most complex and successful state of evolution, has remained neglected. In this plan, an algorithm inspired by the social evolution of humans has been developed in the form of imperialist competitions for optimization. The imperialist competitive algorithm, as with other evolutionary optimization methods, begins with a number of initial populations in which every element of the population is called a country. The countries themselves are categorized into colonized and colonialist. Every colonialist, given its power, dominates a number of colonized countries and controls them [12]. The policy of imperialist competition and absorption constitutes the main core of this algorithm. When presenting this algorithm, this policy proceeds through guiding the colonies of an empire according to a special formulation [13]. Specifically, after division of colonies among the empires and creation of primary empires, the colonies begin to move towards their empire. This movement is a simple model of the simulation policy which used to be adopted by colonialists. Fig. 2 demonstrates the procedure of creation of primary empires, while Fig. 3 indicates the movement of a colony towards its empire.

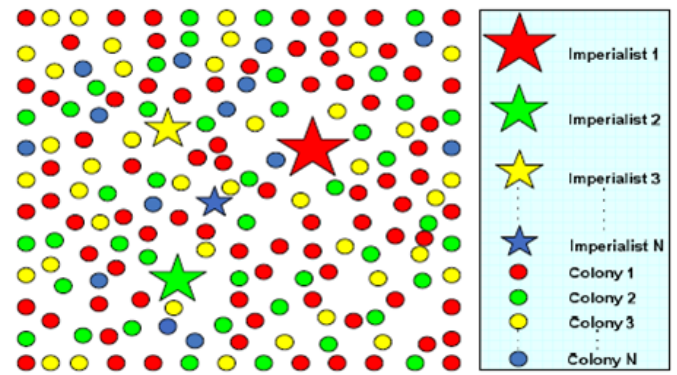


Fig. 2: Creation of the primary empires

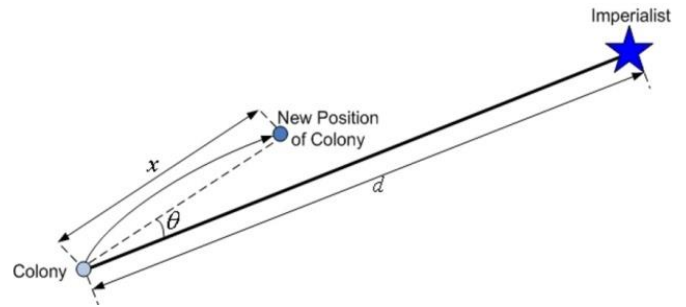


Fig. 3: The movement of a colony toward its related empire

In an imperialist competition, all empires strive to seize the colonies of other empires and control them. This competition usually causes diminished power of empires, while increasing the power of the strongest empires. Fig. 4 demonstrates a modeled outline of the imperialist competition.

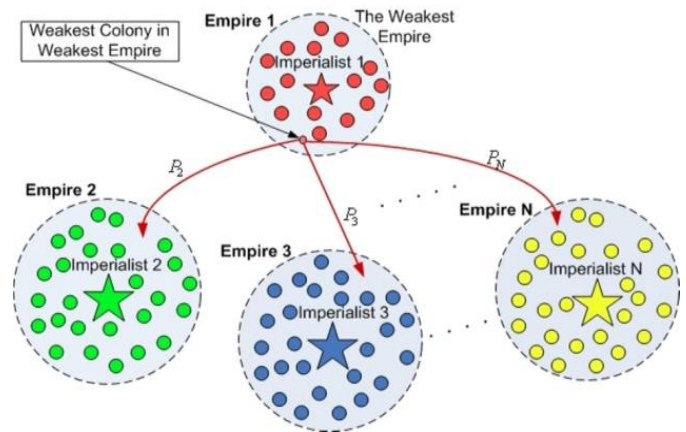


Fig. 4: Seizing the weakest colony of the weakest empire by stronger empires

Any empire which is not able to increase its power (or at least prevent its power decline) in this imperialist competition, will be eliminated [14, 15]. The imperialist competition gradually leads to increased power of the strongest empires and diminished power of the weakest ones. As the power of

weak empires drops, they gradually collapse. The flowchart of the presented method is in the form of Fig. 5.

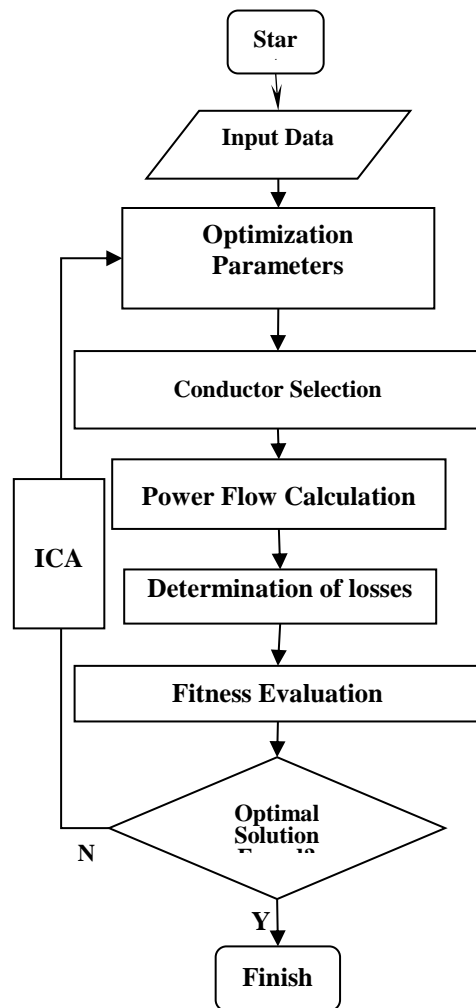


Fig. 5: The flowchart of the proposed method

V. DEPRECIATION ANALYSIS

Before investigating the factors causing depreciation and its impacts on the conductors of the network, we define depreciation. Depreciation refers to reduction of the useful life of effective operation of equipment over time in response to different conditions. Different factors affect depreciation of conductors including climatic conditions, improper design, improper operation in response to excessive loading, and unsuitable implementation of the network by executive agents. Extreme climatic conditions including freezing, snow, rain, wind, and sunlight will have the maximum impact. Then, this depreciation of conductors in the distribution network leads to increase in losses, reduction of the reliability and safety indicators, and diminished income obtained from selling energy. The issue of energy losses is very important for the power industry, and taking care of its reduction is an inevitable necessity. Reduction of electric energy losses generally refers to enhancing the capacity of generation as well as the transmission network and

distributing it without investment in generation. So far, many attempts have been made in this regard, and satisfactory outcomes have been obtained by creating new methods and their application. The issue becomes further important considering the necessity of research in this regard using domestic sources and information and given the natural conditions of the region.

VI. INVESTIGATING THE BEHAVIOR OF DEPRECATED CONDUCTORS OF MEDIUM VOLTAGE NETWORK

From the very beginning stage of fabrication until operation, conductors are always depreciated under the influence of numerous factors. Each of these factors can cause depreciation and eventually irrecoverable damages to the power network lines or the side facilities in some way. Thus, these factors should be identified and some solutions should be proposed to prevent them, albeit incompletely. In designing power transmission lines, in addition to the very effective role of electric parameters, some factors jeopardize them, including the effect the depreciation of conductors because of environmental conditions. Experience has shown that the first stage that may be associated with depreciation effects is the time of fabrication of conductors [16]. It is because any carelessness at this stage can intensify the environmental degrading factors. In addition, not adhering to the standards at the time of installation or cabling as well as application of unsuitable hardware can also lead to depreciation of conductors. Note that this depreciation as with any other component of the power network, is an inevitable process. Early or unpredicted depreciation of conductors of lines can have adverse consequences. High temperature is one of the main reasons for the damage to conductor fibers. Thus, the high temperature factor is considered the major concern for initiation of depreciation especially in warm regions. Furthermore, heat causes the fiber of conductors to loosen whereby they lose their tensile strengths, resulting in diminished safety and functional problems [17]. Functional assessment of the depreciated conductors of the power distribution network plays a significant role in asset management systems. By evaluating the extent of depreciation of conductors that exist in the network and determining the level of losses resulting from this depreciation, the remaining useful life of the network can be determined.

COLLECTION OF THE DEPRECATED CONDUCTORS OF MV POWER DISTRIBUTION NETWORK

The conductors assessed in this paper have been those used in a sample MV network of the southern Kerman power distribution company, Daz feeder from Ghaleganj town with a chainage of 25.6 Km, distributing the power transmission via conductors such as HYENA, DOG, and MINK. Thus, the mentioned conductors, which are the most widely used conductors in MV network, were evaluated. In this research, in the course of nine months in coordination with the Department of design and supervision of the southern Kerman power distribution company, by doing some

optimization projects and cutting MV network for installing pedestrian overpass, some samples of the relevant conductors with the maximum usage in the network with different age ranges were prepared in a chainage of 2 m and collected. For this purpose, samples of different types of conductors at different sizes with various usage years were prepared from the average pressure network. According to the date of the installed posts, we could specify the level of usage of the conductor of each of the sections related to the power distribution networks. After collection, the resistance of the conductors was measured by an Ohmmeter and their wire thickness was also determined in the Islamic Azad University of Kahnooj electrical laboratory. The results of the test of the resistance of conductors at different years are shown in Table I.

TABLE I

The electric resistance of the network conductors in terms of age

Conductor section [mm ²]	R [Ω/km]	Age [year]
70	0.4545	New
70	0.4580	1
70	0.4760	38
120	0.2712	New
120	0.3320	42
126	0.1576	New
126	0.2130	24
126	0.2430	26

VII. STUDIES PERFORMED ON THE SAMPLE NETWORK

In the power distribution networks, a considerable percentage of the energy generated in power plants is lost in the path between generation and consumption, whose value depends on various parameters. The variety, number, and nature of these factors cause different extent of losses even in two seemingly similar networks with the same load. The desirable value of losses in distribution networks is 5%; it is possible to approach this value in practice. Because of different reasons, the extent of losses in the power distribution networks in the country is far larger than that; as such attempts should be made to identify the factors causing the losses and then to reduce them.

As stated earlier, the sample studied network, Daz feeder of Ghaleganj town, is one of the average pressure feeders from power distribution company of south of Kerman province. It was simulated using MATLAB software after field extraction from the mentioned network. The conductors assessed in this paper were HYENA, DOG, and MINK. In the first stage, the Daz feeder of this town from the southern Kerman power distribution company was investigated in laboratory with different types of conductors and then simulated by MATLAB software. Fig. 6 demonstrates the

network of interest schematically and single-linearly, while Tables II and III provide the technical information of Daz feeder of Ghaleganj town.

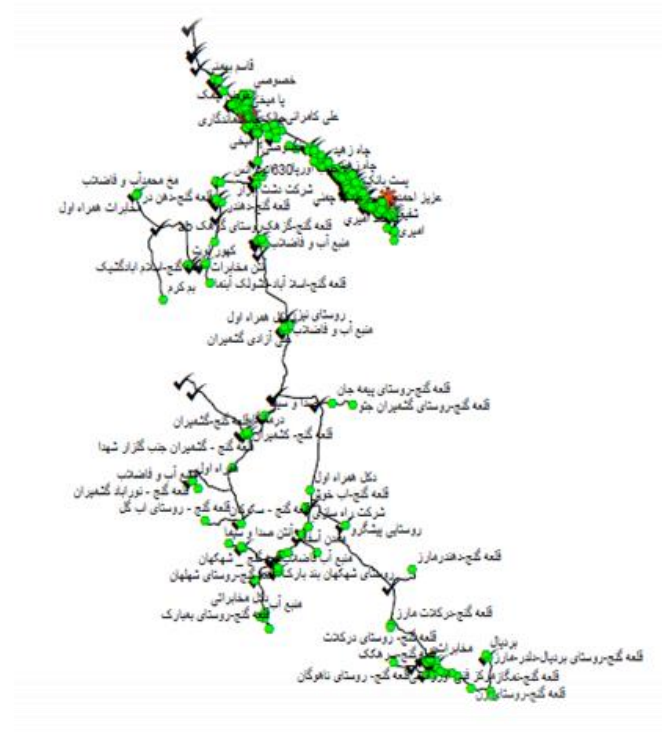


Fig. 6: The schematic view of Daz feeder in Ghaleganj town

TABLE II

Chainage of Daz feeder of Ghaleganj town for different types of conductor or cable

Type of conductor or cable	Conductor length - m
DOG	69383
MINK	168723
HYENA	14583
WASSEL	67701

TABLE III

The capacity of the transformers of Daz feeder in Ghaleganj town

Total capacity(KVA)	Number	Capacity(KVA)
75	3	25
2075	83	25
1000	20	50
6300	63	100
400	2	200
500	2	250
315	1	315

VIII. ANALYSIS OF RESULTS

Selection and reconstruction of the best type and most suitable size of conductors are indispensable parts for the design process according to Table IV for the design and optimization of the distribution network. Fig. 7 is show convergence diagram via ICA method. Fig. 8, 9 and 10 is shows voltage profile, power losses profile and total power losses. Where, a) conventional method, b) optimization by ICA method first mode: reconstruction of the network by a new conductor, c) optimization by ICA method second mode: reconstruction of the network with new and deprecated conductors.

TABLE IV
The specifications of conductors

Type	R [Ω/km]	X [Ω/km]	Cmax [A]	A [mm ²]
Hyena	0.1576	0.2277	550	126
Dog	0.2712	0.2464	440	120
Mink	0.4545	0.2664	315	70
Wasel	0.512	0.289	150	25
Rok	0.235	0.2764	400	35

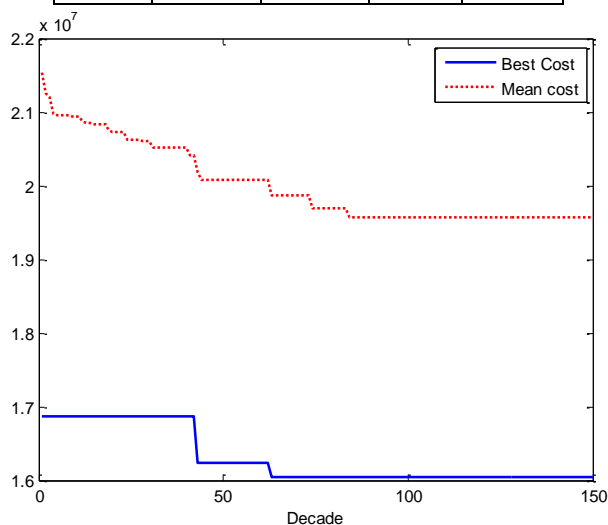


Fig. 7: Convergence diagram via ICA method

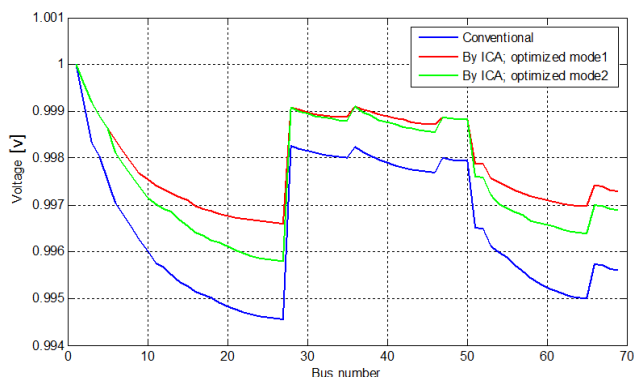


Fig. 8: The sample's system voltage profile in three states of buses

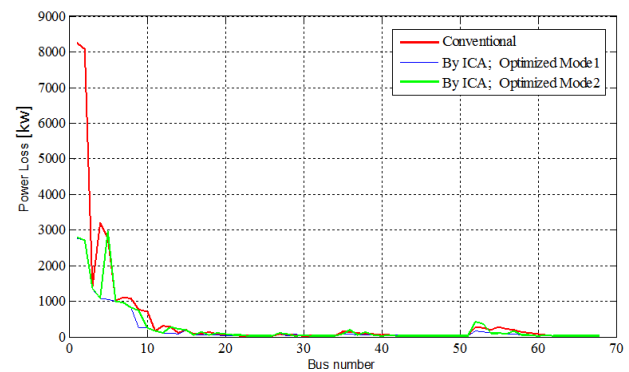


Fig. 9: The profile of the power losses of the sample system in three states for each branch

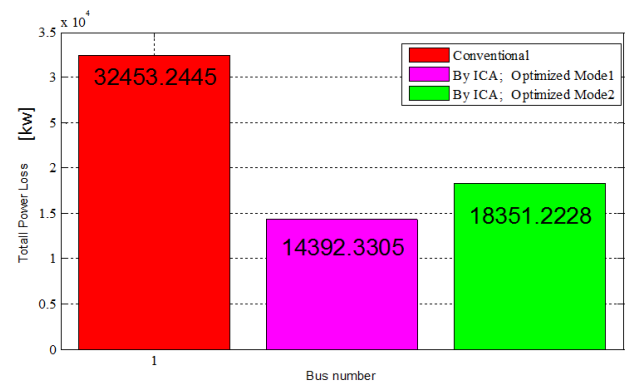


Fig. 10: The diagram of total power losses of the sample system in three states

IX. CONCLUSIONS

In the present study, a novel method was presented through imperialist competitive algorithm (ICA) for selection as well as suitable and optimal incorporation of conductors of radial power distribution network sections considering the effect of depreciation of conductors. The impact of depreciation of conductors present in an average pressure network was tested considering different environmental conditions for reducing the losses and improving the productivity of the network. Through this investigation, the demand of power distribution companies for economical management as well as the demand of the country for optimal productivity of energy resources can be fulfilled along with reduction of investment costs. Increasing the usability of electric energy of the power network for the subscribers was considered per load increment with regards to the development of the country. Selection and optimal construction of conductors in radial networks of power distribution was performed through a smart method for minimizing the costs related to the annual losses as well as investment for renovating the lines in order to improve the productivity of the power distribution network. A novel method was adopted for solving optimization of selection of a power radial distribution network conductor.

CONFLICT OF INTEREST

The authors have no conflict of relevant interest to this article.

REFERENCES

- [1] M. J. Rider, M. Lavorato, R. Romero, "Optimal Conductor Size Selection and Reconductoring in Radial Distribution Systems Using a Mixed-Integer LP Approach", *IEEE Transactions on Power Systems*, Vol. 28, Issue 1, pp. 10-20, 2013.
- [2] Mahdi Mozaffari Legha, Ardalan Zargar Raeiszadeh, Rouhollah Abdollahzadeh Sangrood, Mohammad Mozaffari Legha, "A Practical Approach to the Conductor Size Selection in Planning Radial Distribution Systems for Productivity Improvement Using ICA Approach", *International Journal on Technical and Physical Problems of Engineering (IJTPE)*, Vol. 5, no. 2, pp. 1-5, 2013.
- [3] Hee-Jun Cha, Jin-Young Choi, Dong-Jun Won, "Smart Load Management in Demand Response using Microgrid EMS", *IEEE International Energy Conference (ENERGYCON)*, pp. 833-837, 2010.
- [4] N. L. Diaz, A. C. Luna, J. C. Vasquez, J. M. Guerrero, "Centralized control architecture for coordination of distributed renewable generation and energy storage in islanded AC microgrids", *IEEE Trans. Power Electron.*, Vol. 32, pp. 5202-5213, 2017.
- [5] Hossein Farzin, Rahim Ghorani, Mahmud Fotuhi-Firuzabad, Moein Moeini-Agtaie, "A market mechanism to quantify emergency energy transactions value in a multi-microgrid system", *IEEE Transactions on Sustainable Energy*, Vol. 10, Issue 1, 2017.
- [6] Mahdi Mozaffarilegha, Ebrahim Farjah, "Implementation of energy management of a microgrid using HMAS", *Smart Grid Conference (SGC)*, 2018.
- [7] Franklin Mendoza, Durlym Requena, Jose L. Bemal-agustin, Jose A. Dominguez-navarro, "Optimal Conductor Size Selection in Radial Power Distribution Systems Using Evolutionary Strategies", *IEEE/PES Transmission & Distribution Conference and Exposition: Latin America*, 2006.
- [8] Emad G. Shehata, Maged S. Gaber, Khalil Ali Ahmed, Gerges M. Salama, "Implementation of an energy management algorithm in DC MGs using multi-agent system", *Int Trans Electr Energy Syst.*, 2018
- [9] M. Mozaffari Legha, E. Farjah, "IOT Based Load Management of a Micro-Grid Using Arduino and HMAS", *Iranian Journal of Electrical and Electronic Engineering*, Vol. 16, Issue 2, 2020.
- [10] Franklin Mendoza, Durlym Requena, Jose L. Bemal-agustin, Jose A. Dominguez-navarro, "Optimal Conductor Size Selection in Radial Power Distribution Systems Using Evolutionary Strategies", *IEEE/PES Transmission & Distribution Conference and Exposition: Latin America*, 2006.
- [11] M. Ramalinga Raju, K.V.S. Ramachandra Murthy, K. Ravindra, R. Srinivasa Rao, "Optimal conductor selection for agricultural distribution system - a case study", *International Conference on Intelligent and Advanced Systems*, 2010.
- [12] Daniel E. Olivares, Claudio A. Cañizares, and Mehrdad Kazerani, "A Centralized Energy Management System for Isolated MicroGrids", *IEEE Transactions on Smart Grid*, Vol. 5, No. 4, July 2014.
- [13] M. Vahid, N. Manouchehr, S. D. Hossein, and A. Jamaledin, "Combination of optimal conductor selection and capacitor placement in radial distribution systems for maximum loss reduction", in *Proc. 2009 IEEE Int. Conf. Industrial Technology, Gippsland, Australia*, pp. 01-05, 2009.
- [14] Mahdi Mozaffari Legha, Hassan Javaheri, Mohammad Mozaffari Legha, "Optimal Conductor Selection in Radial Distribution Systems for Productivity Improvement Using Genetic Algorithm", *Iraqi Journal for Electrical and Electronic Engineering (IJEEE)*, Vol. 9, No. 1, pp. 29-35, 2013.
- [15] Mozaffari Legha, (2011) "Determination of exhaustion and junction of in distribution network and its loss maximum, due to geographical condition" MS.c Thesis. Islamic Azad University, Saveh Branch, Markazi Province, Iran.
- [16] Mahdi Mozaffarilegha, Sanaz Rashidifard, Mohammad Mozaffarilegha, "Optimum implementation renewable energy systems in remote areas", *Iraqi Journal for Electrical and Electronic Engineering (IJEEE)*, Vol. 16, Issue 2, pp.126-130, 2020.
- [17] Sudipta Mohanty;Kumari Kasturi;Manas Ranjan Nayak, "Application of ER-WCA to Determine Conductor Size for Performance Improvement in Distribution System", *International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, 2021.