

Improving Reliability from View of Buyer-Seller by Optimal Reconfiguration: Applicability to Lorestan Distribution Network

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Abstract

Reconfiguration of distribution networks by a series of switching operations is a simple and inexpensive way to improve reliability and reduce power losses, which without the addition of additional equipment to the network, makes optimal use of distribution systems. In this paper, optimal reconfiguration is proposed to improve reliability and minimize power losses as objective functions. To demonstrate the functionality and applicability of the proposed method, five states are defined based on the trade-off between buyer-seller. Particle swarm optimization (PSO) algorithm has been used to solve this problem. Then, the proposed method has been implemented on the Lorestan Distribution Network.

Keyword: Reliability improvement; Power loss reduction; Particle swarm optimization algorithm; Lorestan distribution network.

Nomenclature and Units

$CENS$	Cost of Energy Not Supplied
DG	Distributed Generation
DN	Distribution Network
I_i	i Bus Current Intensity
$MAIFI$	Momentary Average Interruption Frequency Index
OF	Objective Function
P_{DG_i}	i Bus Power Distributed Generation
P_{di}	i Bus Active Power Demand
P_{gi}	i Bus Active Power Generation
P_L	Power Load
P_{slack}	Slack Bus Power
PSO	Particle Swarm Optimization
Q_{di}	i Bus Reactive Power Demand
Q_{gi}	i Bus Reactive Power Generation
$SAIDI$	System Average Interruption Duration Index
$SAIFI$	System Average Interruption Frequency Index
V_i	i Bus Voltage
Y_{ij}	i & j Bus Matrix Admittance
δ	Angles of Voltage Bus
θ	Admittance Angle

Introduction

Between 30% to 40% of the total investment in the power system is in the distribution sector. One of the leading challenges in Distribution Networks (DNs) is the proper design of the network to improve reliability and reduce power losses. The high level of power losses and the low level of network reliability are distributed over other parts of the power system (generation and transmission),

resulting in large charges imposed on the network. Due to the growth of electric power consumers and the constraints on generation and transmission, the DN has been exploited under overload conditions. The statistical results indicate that most power failures occurred in the DN [1]. There are several ways to reduce losses in the DN. Many methods require new equipment in the installation system, and this additional equipment, in addition to having financial burdens for companies (which may sometimes cost more social benefits), may cause new faults on the network disturbs the service to subscribers. To overcome these problems, initially, the reconfiguration method with no need to install new devices on the DN, and with the same switches, it simply reduces the cost of the losses. There are usually a number of normally open switches and a number of normally close switches in each DN. By closing some common-state switches open and opening the same number of normal shut-off switches, the power distribution path in the DN can be changed so that System losses will be reduced. Subsequently, since the DNs are always used radially, the reconfiguration should be such that the radial structure of the DN is preserved. Reconfiguration transforms the DN structure by switching the switch state. These switches can be divided into two categories: switchers (normally close) and connection switches (normally open) [2]. In fact, by changing the DN structure, the states of the switches should change. Hence, most DNs are radial across the world, because there are some

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limitations for them. Some of these limitations include the maintenance of radial structure, load balancing and non-overloading of devices [3].

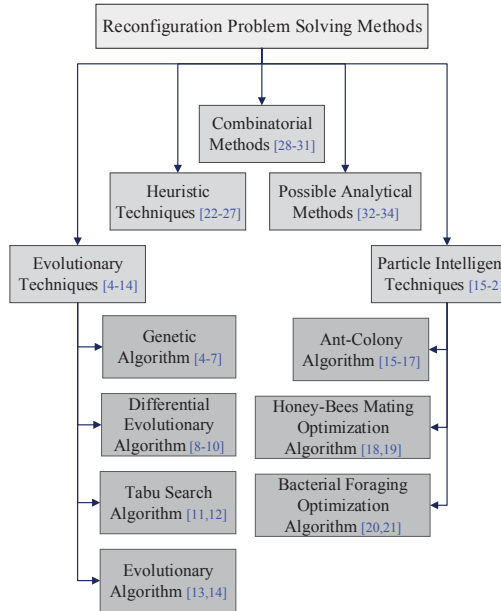


Figure 1. Categorization of reviewed articles based on reconfiguration of DN

Figure 1. is a relatively comprehensive overview of the most recent published articles about the distribution network reconfiguration. In the study process, articles are grouped based on problem-solving techniques.

The remainder of this paper is structured as follows: Formulating Structure for objective function and constraint relations are proposed in section 2. The concept of the proposed PSO and solving the optimal reconfiguration of Lorestan DN using PSO algorithm has been presented in section 3. Based on the proposed algorithm, the simulation results are provided in Section 4 and the last part is about the conclusion in Section 5.

Formulating the Proposed Method

1.1 Objective Function

The main challenge at this technical stage is to introduce the objective function of the problem. The four parameters of reliability and power losses defined in the objective function are very different in quantitative terms, which are used by the normalization technique to include these parameters in the objective function. For this purpose, the values of the trivial parameters of the objective function are divided into pre-position values. With this technique, each parameter is normalized to a logical and scientific basis.

$$OF = SAIDI + SAIFI + CENS + MAIFI + Loss \quad (1)$$

In some references, it is seen that weighting factors have been used to solve such problems which, given the initialization of these factors by the user (with the sum of factors equal to 1), is not a logical way to solve such problems, and in the effect of the parameters with lower values in the function the goal is reduced. By this technique values of four indices are normalized.

1.2 Objective Function

The constraints of the problem are two parts. The first part contains the constraints of distributed generation resources, which include the number and limits of active and reactive power of each source. The other part of the constraint is the permissible voltage limit on the network loads, so that during the formation of the island, the voltage on the loads should not exceed the permissible limits.

- **Load Flow Constraint:** The accuracy of the load flow is the first step in determining the optimal capacity of the DG. However, the observance of the load flow in solving power system problems is obvious, but its expression is indicative of its importance. The relations (2) and (3) show the load distribution relations for active and reactive power.

$$P_{gi} - P_{di} - V_i \sum_{j=1}^n V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (2)$$

$$Q_{gi} - Q_{di} - V_i \sum_{j=1}^n V_j Y_{ij} \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (3)$$

- **Constraint power balance:** The injectable power of bus slack and the power generated by the DG units should be equal to the generation resources with the total power consumption of network load points and network losses.

$$P_{Slack} + \sum_{i=1}^N P_{DG_i} = \sum_{i=1}^N P_{D_i} + P_L \quad (4)$$

- **The bus i voltage range:** The installation of DG units should not increase the voltage of one bus above the value of V_i^{\max} (1.05 PU) or reduce the voltage of one bus to less than V_i^{\min} (0.95 PU).

$$|V_i|^{\min} \leq |V_i| \leq |V_i|^{\max} \quad (5)$$

- **Flow current from the i-th line:** The proposed scheme for the installation of DG units should not increase the flow current of network lines more than the nominal value of feeders; in fact, this indicates the limit of the feeder current flow.

$$|I_i| \leq |I_i|^{\max} \quad (6)$$

Solving the Problem by Proposed PSO Algorithm

The particle swarm optimization algorithm (PSO) algorithm is used to solve various problems in power systems. The concept of PSO is discussed [35-36]. In the following, the optimal reconfiguration of Lorestan Distribution Network problem solution by PSO algorithms discussed.

In this algorithm, initially, by entering the system information, the load flow program was done by considering the constraints of the load flow problem. Then, using the sensitivity analysis presented, the candidate buses for determining the state of the switch are determined. Finally, the values of the objective function, including reliability indices and loss based on the candidate buses, are calculated. Figure 2. shows the proposed flowchart of optimal reconfiguration solution by the PSO algorithm in order to find the state of switching in which improves the reliability indices and reduces power loss in Lorestan DN.

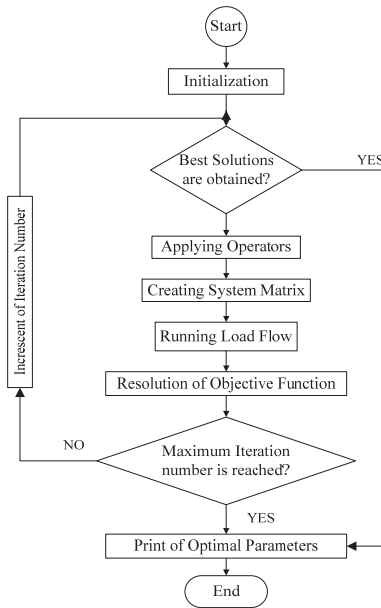


Figure 2. Solving the optimal reconfiguration of Lorestan DN using PSO algorithm

Simulation Results

To demonstrate the superiority of the proposed retrofit technique, a case study was conducted on the Lorestan DN. A single line diagram of this network is presented in Figure 3. For the above network, 25 loops can be defined. To determine the effect of automation switches, six states are defined for this network. These states are designed to change the number of transient faults (in terms of number per year) and the duration of fault detection (in terms of hours). Table

1. shows the five states discussed. Now for each state, four scenarios are designed:

Table1. Five states based on the trade-off between buyer-seller[37]

State	Fault detectiontime	Number of transient faults
1	0.05	5
2	0.05	11
3	0.05	16
4	0.01	5
5	0.01	11

- **Scenario 1: Basic state**

In this scenario, the definition of different failure rates and prioritization of the subscriber's study has been done.

- **Scenario 2: With the same relative failure rate**

To design this scenario, we define the entire failure rate as 1, so that the failure rate difference does not affect the results.

- **Scenario 3: Regardless of the importance of the subscribers**

The importance of subscribers in 1, its impact on predicted outcomes.

- **Scenario 4: With the same relative failure rate, regardless of the subscriber's importance**

In this scenario, the reconfiguration is carried out without considering the importance of the subscribers and the different failure rates.

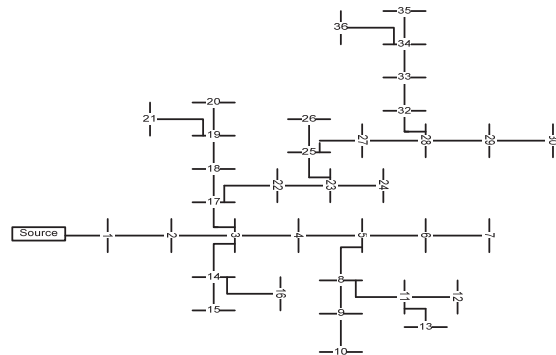


Figure 3. Single line diagram of the Lorestan DN[37]

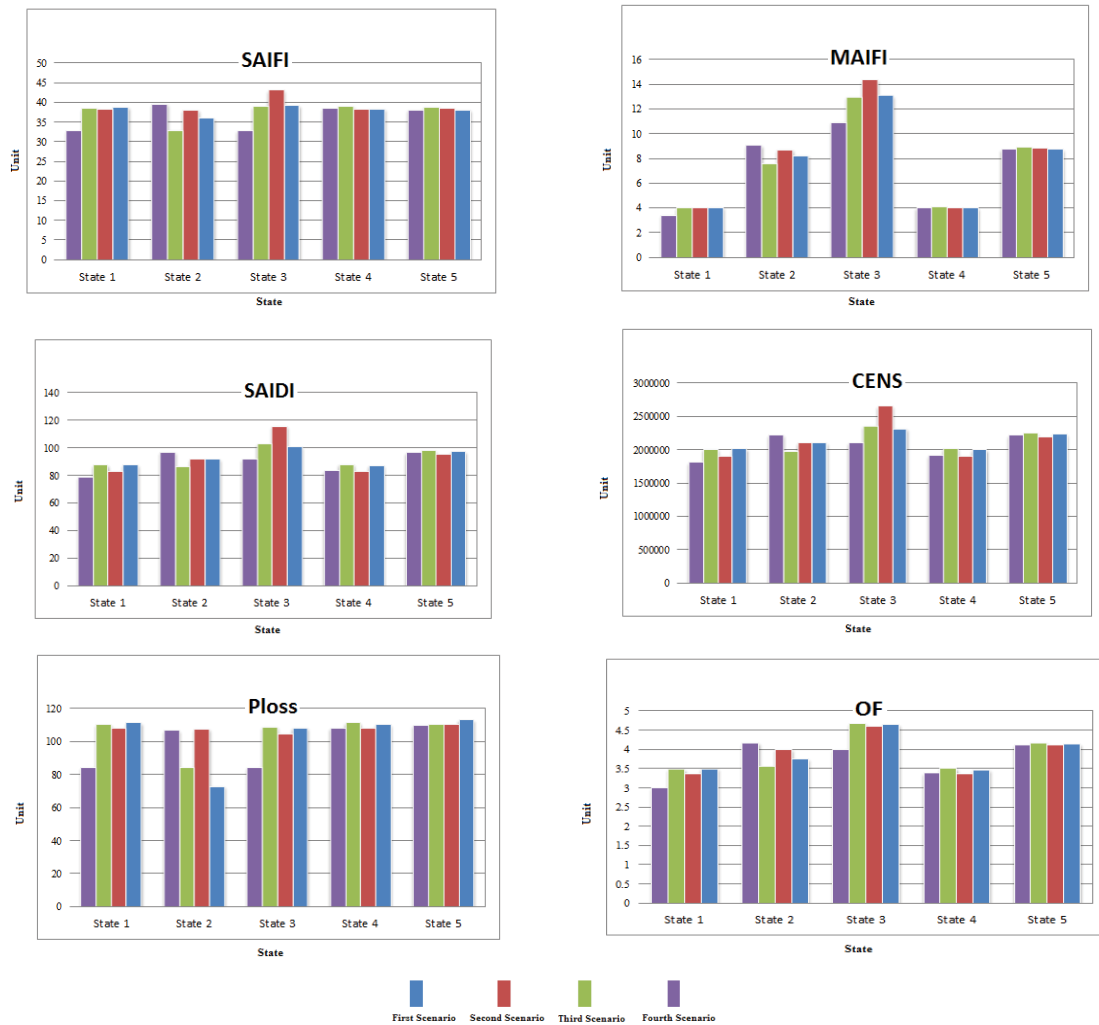


Figure 4. The results of applying four scenarios on the Lorestan DN

Table 2. switch codes derived from different scenarios and states

Scenario	State 1	State 2	State 3	State 4	State 5
1	4 32 8 9 29	6 25 27 8 22	33 6 10 5 29	5 33 7 9 29	33 7 8 5 29
2	33 7 29 10 5	10 32 5 7 29	33 27 36 35 7	33 7 29 10 5	7 5 9 29 33
3	8 33 5 29 9	22 31 10 3 22	29 5 7 32 9	4 32 8 9 29	7 5 9 33 30
4	22 31 10 3 22	32 7 10 29 5	10 31 22 23 2	33 10 5 29 7	5 6 9 33 30

According to the results obtained in Fig. 4:

- The best value for subscribers SAIFI is obtained in the fourth scenario of the first and third states. The worst case is also obtained in the second scenario of the third state.
- The best and worst for MAIFI are obtained in the fourth scenario of the first state and the second scenario of the third state, respectively.
- The best value of SAIDI is obtained in the fourth scenario of the first state, and the worst possible amount is seen in the third scenario of the fifth and sixth states.

- CENS index is the best in the fourth scenario of the first state, and in the second scenario the third state is the worst.
- The lowest possible power losses in the fourth scenario of the first state, the third scenario of the second state and the fourth scenario of the third state are presented. The highest amount of power losses is obtained in the first scenario of the fifth and sixth states.
- The best possible value for the OF is obtained in the fourth scenario of the first state and the worst possible in the third scenario of the third state.

Table (2) shows the status of the switch codes in different scenarios and states.

CONCLUSION

In this paper, the problem of reconfiguration of DN with the purpose of improving the capability is carried out. For this purpose, four reliability parameters are considered in the formulation of the problem, which are: SAIFI, SAIDI, AENS, and MAIFI. Also, power losses are included in the objective function. Selection of parameters has been selected based on improved reliability from the buyer-seller's point of view and improved reliability of transient and permanent faults. The problem is optimized using PSO algorithm. The simulation has been performed on the Lorestan DN with four scenarios designs. From simulation results it can be asserted that, except for the first and third states, in the rest of the states the second scenario has the best answer. On the other hand, with the exception of the first two states, the first scenario is the worst, in the rest of the state, the fourth scenario produces the worst response.

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REFERENCE

- [1] Falah, nezhadnaeini, M., Hajivand, M., Karimi, R., Karimi, M., Optimal Recloser Placement by Binary Differential Evolutionary Algorithm to Improve Reliability of Distribution System, *International Journal of Information, Security and Systems Management (IJISSM)*, 3(2), 2014, 345-349.
- [2] Amanulla, B., Chakrabarti, S., and S. N. Singh, Reconfiguration of power distribution systems considering reliability and power loss, *IEEE Transactions on Power Delivery*, 27(2), 2012, 918-926.
- [3] Sivkumar, M., Debapriya, D., and Subrata, P., comprehensive review on power distribution network reconfiguration, *IEEE Transactions on Power Delivery*, 8(2), 2017, 227-284.
- [4] Gupta, N., Swarnkar, A., Niazi, K.R. Distribution network reconfiguration for power quality and reliability improvement using Genetic Algorithms, *Electrical Power and Energy Systems*, 2014, 54, 664-671.
- [5] Mendoza, J., López, R., and Morales, D. Enrique López, Philippe Dessante, and Roger Moraga, Minimal loss reconfiguration using genetic algorithms with restricted population and addressed operators: real application, *IEEE Transactions on Power Systems*, 21(2), 2006, 948-956.
- [6] Din, D.R., Chiu, Y.Sh. A genetic algorithm for solving virtual topology reconfiguration problem in survivable WDM networks with reconfiguration constraint, *Computer Communications*, 31, 2008, 2520-2533.
- [7] Bogdan, E., Bertrand, R., Raphael C., Olivier D., Wojciech B., Nouredine H., Radial Network Reconfiguration Using Genetic Algorithm Based on the Matroid Theory, *IEEE Transactions on Power Systems*, 23(1), 2008, 186 - 195.
- [8] Chiou, J.P., Chang, Ch.F., and Su, Ch.T, Variable Scaling Hybrid Differential Evolution for Solving Network Reconfiguration of Distribution Systems, *IEEE Transactions on Power Systems*, VOL. 20(2), 2005, 668-674.
- [9] Jazebi, S., and Vahidi, B. Reconfiguration of distribution networks to mitigate utilities power quality disturbances, *Electric Power Systems Research*, 91, 2012, 9-17.
- [10] Jazebi, S., Hosseinian, S.H., and Vahidi, B. DSTATCOM allocation in distribution networks considering reconfiguration using differential evolution algorithm, *Energy Conversion and Management*, 52(7), 2011, 2777-2783.
- [11] Abdelaziz, A.Y., Mohamed, F.M., Mekhamer, S.F., and Badr, M.A.L. Distribution system reconfiguration using a modified Tabu Search algorithm, *Electric Power Systems Research*, 80, 2010, 943-953.
- [12] Zhang, D., Fu, Zh., and Zhang L. An improved TS algorithm for loss-minimum reconfiguration in large-scale distribution systems, *Electric Power Systems Research*, 77, 2007, 685-694.
- [13] Resende Barbosa, C.H. N., Soares Mendes, M.H., and Antônio de Vasconcelos, J. Robust feeder reconfiguration in radial distribution networks, *Electrical Power and Energy Systems*, 54, 2014, 619-630.
- [14] Ebrahimi Milani, A., Haghifam, M.R. An evolutionary approach for optimal time interval determination in distribution network reconfiguration under variable load, *Mathematical and Computer Modelling*, 57, 2013, 68-77.
- [15] Su, Ch.T., Chang, Ch.F., and Chiou, J.P. Distribution network reconfiguration for loss reduction by ant colony search algorithm, *Electric Power Systems Research*, 75, 2005, 190-199.

- [16] Swarnkar, A., Gupta, N., and Niazi, K.R. Adapted ant colony optimization for efficient reconfiguration of balanced and unbalanced distribution systems for loss minimization, *Swarm and Evolutionary Computation*, 1(3), 2011, 129-137.
- [17] Carpaneto, E., Chicco G., Distribution system minimum loss reconfiguration in the hyper-cube ant colony optimization framework, *Electric Power Systems Research*, 78(12), 2008, 2037-2045.
- [18] Olamaei, J., Niknam, T., badali, S., and Arefi, F. Distribution Feeder Reconfiguration for Loss Minimization Based on Modified Honey Bee Mating Optimization Algorithm, *Energy Procedia*, 14, 2012, 304-311.
- [19] Resende Barbosa, C.H. N., Soares Mendes, M.H., and Antônio de Vasconcelos, J. Robust feeder reconfiguration in radial distribution networks, *Electrical Power and Energy Systems*, 54, 2014, 619-630.
- [20] Niknam, T., Kavousi Fard, A., and Seifi, A. Distribution feeder reconfiguration considering fuel cell/wind/photovoltaic power plants, *Renewable Energy*, 37, 2012, 213-225.
- [21] Sathish Kumar, K., and Jayabarathi, T. Power system reconfiguration and loss minimization for an distribution systems using bacterial foraging optimization algorithm, *Electrical Power and Energy Systems*, 36, 2012, 13-17.
- [22] Gil Mena, A.J., and Martin Garcia, J.A. A new heuristic approach for optimal reconfiguration in distribution systems, *Electric Power Systems Research*, 83, 2012, 264-265.
- [23] Niknam, T., Kavousi Fard, A., and Baziar, A. Multi-objective stochastic distribution feeder reconfiguration problem considering hydrogen and thermal energy production by fuel cell power plants, *Energy*, 42, 2012, 563-573.
- [24] Pfitscher, L.L., Bernardon, D.P., Canha, L.N., Montagner, V.F., Garcia, V.J., and Abaide, A.R. Intelligent system for automatic reconfiguration of distribution network in real time, *Electric Power Systems Research*, 97, 2013, 84-92.
- [25] Zidan, A., Shaaban, M.F., El-Saadany, E.F. Long-term multi-objective distribution network planning by DG allocation and feeders' reconfiguration, *Electric Power Systems Research*, 105, 2013, 95-104.
- [26] J.S. Rosseti, G., J. de Oliveira, E., W. de Oliveira, L., C. Silva Jr., I., and Peres, W. Optimal allocation of distributed generation with reconfiguration in electric distribution systems, *Electric Power Systems Research*, 103, 2013, 178-183.
- [27] José de Oliveira, E., José Rosseti, G., Willer de Oliveira, L., Vanderson Gomes, F., Peres, W. New algorithm for reconfiguration and operating procedures in electric distribution systems, *Electrical Power and Energy Systems*, 57, 2014, 129-134.
- [28] Niknam, T., Azadfarani, E., and Jabbari, M. A new hybrid evolutionary algorithm based on new fuzzy adaptive PSO and NM algorithms for Distribution Feeder Reconfiguration, *Energy Conversion and Management*, 54, 2012, 7-16.
- [29] Shariatkhan, M.H., Haghifam, M.R., Salehi, J., and Moser, A. Duration based reconfiguration of electric distribution networks using dynamic programming and harmony search algorithm, *Electrical Power and Energy Systems*, 41, 2012, 1-10.
- [30] Hooshmand, R., and Soltani, S.H. Simultaneous optimization of phase balancing and reconfiguration in distribution networks using BF-NM algorithm, *Electrical Power and Energy Systems*, 41, 2012, 76-86.
- [31] Tomoiaga, B., M., Chindris, Sumper, A., Villafafila-Robles, R., and Sudria-Andreu, A. Distribution system reconfiguration using genetic algorithm based on connected graphs, *Electric Power Systems Research*, 104, 2013, 216-225.
- [32] Zhang, P., Li, W., and Wang, Sh. Reliability-oriented distribution network reconfiguration considering uncertainties of data by interval analysis, *Electrical Power and Energy Systems*, 34, 2012, 138-144.
- [33] Milani, A.E., and Haghifam, M.R. A new probabilistic approach for distribution network reconfiguration: applicability to real networks, *Mathematical and Computer Modelling*, 57, 2013, 169-179.
- [34] Firas M. F. F., Xiangning L., Mohammed Kdair A., Samir M. D., Zhengtian L. and Owolabi S. A., A New Method for Distribution Network Reconfiguration Analysis under Different Load Demands, *Energies*, 10(4), 2017, 1-19.
- [35] Eberhart R.C., Shi Y., Particle swarm optimization: Developments, Applications and resources, *Proceedings of the 2001 Congress on Evolutionary Computation*, 1, 2001, 81-86.
- [36] Al Rashidi M.R., El-Hawary M.E., A survey of particle swarm optimization Applications in electric power systems, *IEEE Transactions on Evolutionary Computation*, 13(4), 2006, 913-918.
- [37] Electricity Province Distribution Company, Lorestan, Iran. <https://www.http://www.ledec.ir>.