Distribution Network Reconfiguration using PSO Algorithm with DLMP Application

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Abstract

The topic of distribution network reconfiguration has been recognized as a common problem in the operation of distribution networks. Up to now, reconfiguration of the distribution network has been used to reduce power loss, issues with reliability and emergency problems. As a result of the increasing installation rate of Distributed Generations (DGs) and the increasingly increasing number of Electric Vehicles (EVs), distribution network operators have faced new problems as a result of high sensitive loads. These new facets of the problem of network operation consist of the problem of congestion and enable the business mechanism to be executed by an existing distribution market. With the application of Distribution Locational Marginal Price (DLMP), using Particle Swarm Optimization (PSO), this paper introduces a new methodology to solve this problem. As a suitable case study, the standard IEEE 33-bus network has been selected and simulation results show the compatibility of the proposed system. In the case of not considering DGs and the problem of congestion, comparisons with other papers were also discussed. The participation of DGs in the electricity distribution industry, the issue of congestion and the numerical results have been shown and discussed below.

Keywords: Distribution network reconfiguration; Distribution Locational Marginal Price; Distributed Generation; Optimization.
Article history: Received 21-Jan-2021; Revised 30-Jan-2021; Accepted 02-Feb-2021.

1. Introduction

Network reconfiguration is defined as the method of adjusting the state of sectionalization (normally closed) and tie switches (normally open). Based on the power transmission from dense-loaded to light-loaded feeders, these improvements can usually be aimed at preserving network constancy or reducing network loss. In one feeder, it can also be carried out to move the load among substations. Such changes in network structure should be tested in order not to break the limits of protection and stability. In addition, the network should retain its radial topology in the distribution systems. The reconfiguration of the distribution feeder can be a organization and operational challenge, where it can be used for cyclical assessments and real-time choices. Network reconfiguration is usually seen as Mixed-Binary Nonlinear Optimization (MBNLP), where binary variables signify the formal of network switches and the power network is modelled by continuous variables. Some of the objective functions of typical network reconfigurations are to mitigate loss, load balancing, enhancement of the voltage profile and service Rebuilding. Merlin and back to 1975 are the first studies of network reconfiguration [1]. With heuristic techniques, this study targeted to reduce power loss, where all switches are closed at first and each step involves opening one switch, and this method stays until the radial topology has been attained. This process has been strengthened by Shirmohammadi and Hong, and Some disadvantages, such as not considering delivery, were removed. Restrictions on the network and angle of voltage. Later on, at the first stage, Baran and wu used the key idea of closing all switches, but they last their strategy to decide the loop with the most Loss, using the flow of power

[2,3]. Afterwards, it considers the branch with The biggest lack of control and chooses to open it. This step Until the best minimal loss formation has been achieved, To have been obtained. The loop generated by closing the tie switches is shown in[4]. The technique continues by opening each closed-switch and at each stage the power flow is performed. The switch that leads to a more significant loss reduction has subsequently been selected to alteration its state. On the opposing, all network switches are firstly opened in[4], then a specified list of applicant switches is used to determine the one switch that can be opened. The lowest loss of control. In [6], minimization of delivery failure was implemented using network reconfiguration by distributed generation penetration. Some recent papers use Meta-Heuristic Approaches & Computational Intellect in addition to the heuristic approach. A PSO algorithm is a common way to solve problems with MBNLP[5,6].

The Locational Marginal Prices (LMP) is the cornerstone for the new wave of U.S. electricity market design. LMP has been suggested by FERC as a way of achieving short- and long-term performance in extensive markets for electricity[8]. DLMP can be disintegrated into three parts, similar to the transmission LMP, Such as marginal cost of electricity, marginal cost of loss and marginal cost of congestion. The assignment of the DLMP as a price signal enables customers to respond appropriately, resulting in the optimal operation of the distribution system [9]. With a high level of electric vehicle (EV) penetration, overcrowding in the distribution system can occur without suitable control [10]. The congestion management approach based on Optimal Power Flow (OPF) is based on a central power flow method.

Optimization and was considered to be the most precise and efficient method for congestion management [11]. Market-based, relative to other methods of congestion management, Methods of congestion management can optimize communal welfare, thus causing clients the least frustration and inconvenience [12]. In the MATLAB setting, the DLMP calculation was built based on the optimal power flow solver from the MATPOWER simulation package [13].

Most research on the reconfiguration of the distribution network addressing loss minimization and its purpose role are solely aimed at reducing the cost of loss. Strong microgrid and EV penetration rates as receptive loads and distributed generation (DG) intensify the impression of the cost of energy and Cost of congestion in delivery networks. These two terms are not negligible in assessing the DLMP. In the presented paper, the reconfiguration of the distribution network was tackled with the use of DLMP using the PSO, while also researching the need to use DLMP.

2. Problem Formulation

The OPF was performed in an AC model with the voltage scales and reactive power limit taken into account. In this paper, as shown below, the objective function was aimed at minimizing the total cost.

Objective function:

$$min_{\theta,V_m,P_g,Q_g} \sum_{i=1}^{n_g} f_P^i\left(P_g^i\right) + f_Q^i\left(q_g^i\right) \quad (1)$$

Subject to:

$$\left|F_f(\theta,V_m)\right| - F_{max} \leq 0 \quad (2)$$

$$\left|F_t(\theta,V_m)\right| - F_{max} \leq 0 \quad (3)$$

$$X_{min} \leq X \leq X_{max} \quad (4)$$

$$P_{bus}(\theta,V_m) + P_d - C_g P_g = 0 \quad (5)$$

$$Q_{bus}(\theta,V_m) + Q_d - C_g Q_g = 0 \quad (6)$$

Equation (5) & (6) symbolize the power balance restraints, where P_{bus} & Q_{bus} are the injected power from bus i to other buses and P_d & Q_d are the demand power that should be providing in bus i. A sparse $\eta_{bus} * \eta_{gen}$ generator connection matrix C_g can be definite in a way that its (i, j)th element is 1, provided that generator number j has been located at bus i and 0 otherwise. The maximum line flow is defined by F_{max}. In addition, f and t are indices that match to the injection "from bus" or "to bus" labels. In the following, equation (4) sets voltage angle and magnitude bands, active power of the generator and reactive power of the generator.

3. Proposed Method

A new approach is introduced in the presented paper to achieve optimum network reconfiguration at the level of delivery. Through the implementation of DLMP, this new approach aims to reduce operating costs using PSO. To measure the chromosome fitness, optimum power flow has been executed. It should be remembered that all loads must be fed to each bus, while the topology of the network preserves its radial shape without creating loops. In addition, the network formation should be linked and no island section should be created. Problem-solution algorithm has been exhibit as fig.1.

ISSN: 2251-9246
EISSN: 2345-6221

A) Particle Swarm Optimization

His unit examines the fundamentals of Particle Swarm Optimization and then formulates an intelligent PSO-based search technique and finds all practicable distribution system formations that fulfill the objective function. The algorithm preserves a subdivision population, each preserving a distinctive answer. The subdivisions are connected to a randomized speed and are flown through the space of the multi-dimentional seach. The initialized subdivision population with random position X_i, velocity V_i and objective function F_i are appraised as input parameters using positional synchronizes and population dimension. Every subdivision keeps track of its location and is called Pbest, which is the best amount attained so far. At the same time, Gbest is stored as the overall best amount obtained by any subdivision so far.

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} * iter \tag{7}$$

The weight of inertia dynamically affects the effect of the previous velocity on the subdivision's current velocity. Experimentally, the decreasing assessment of inertia weight lengthways the iterations is shown to trigger linear exploration and exploitation.

$$V_{ij}^{t+1} = W * V_{ij}^{t} + C_1 r_{1j}^{t}[P_{best} - X_{ij}^{t}] + C_2 r_{2j}^{t}[G_{best} - X_{ij}^{t}] \tag{8}$$

where,
v_{ij}^{t} is the subdivision's speed
x_{ij}^{t} is the subdivision's situation

C_1 is the rational parameter and C_2 is the community parameter that reflects the weighting of the term of stochastic hastening that pulls each subdivision respectively to Pbest and Gbest.

r_1 and r_2 are the accidental values that ranges from 0 to 1.

$$x_{ij}^{t+1} = \begin{cases} 1, & if\ u_{ij}^{t} < s_{ij}^{t} \\ 0, & if\ u_{ij}^{t} \geq s_{ij}^{t} \end{cases} \tag{9}$$

Where
u_{ij}^{t} is the random number selected from a identical distribution in (0,1), and
s_{ij}^{t} is the sigmoid function denoted by,

$$s_{ij}^{t} = \frac{1}{1 + e^{-V_{ij}^{t+1}}} \tag{10}$$

This function transforms values from incessant to separate. The overhead function differs, so that the values are selected from the set of switches provided by the bus system.

B) Algorithm

- Initialize the population, location, random velocities, iterations of Pbest, Gbest and Limit, and the matrix from which the amounts of the switch are chosen.
- The weight of inertia is determined, the velocity is updated and the positions of the subdivisions are updated.
- Radiality limit is verified, followed by the Pbest's fitness feature calculation. If the estimated fitness function is lower than the preceding best value, Pbest is modified.
- Similarly, Gbest's fitness feature is evaluated and it is modified if the value is less than that of the previous version.
- If the maximum iterations are reached or if no new better shapes are found, the search algorithm is terminated.
- Change the speed of the subdivisions using the preceding speed, the distance to Pbest and the distance to Gbest in equation 12, if the conditions are not met.
- The location of the subdivisions from the supplied switches is changed. The algorithm is performed from step 3 by this new position regular and speed. Figure 1 displays the suggested Binary Particle Swarm Optimization flowchart for reconfiguration.

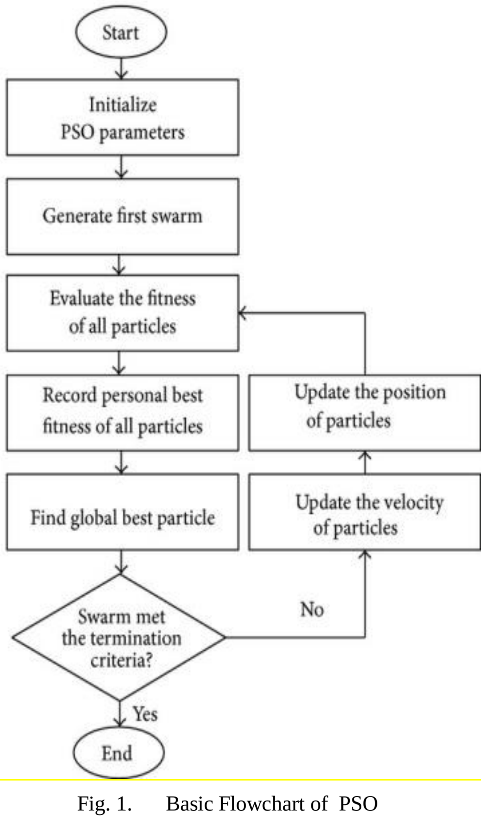

Fig. 1. Basic Flowchart of PSO

4. Numerical Results

Simulations are split into two clusters in order to assess the value of using DLMP in network reconfiguration. The first section discusses the reconfiguration of the network without taking into account distributed generator penetration and the problem of congestion. These assumptions trigger the determination of DLMP regardless of energy costs and congestion costs and seek to minimize the cost of failure. That being said, with the existence of dispersed generations, the second part requires the costs of electricity and congestion.

A) Case Study

Fig. 2 displays the standard IEEE 33-bus system's single line diagram. The topology of the feeder formation, as it is represented, is radial and power flow is unidirectional, where the reference bus is bus number 1. In Figure 1, the dotted lines show the lines opened by the tie switches, and the straight lines indicate the lines opened by the sectionalized switches. The standard IEEE 33-bus system has a total active power and reactive power of 3715 kW and 2290 kVAR, respectively. It should also be remembered that the price for bus 1 was believed to be 20 $/MWh. See Appendix A for more detail relating to the data used in implementation.

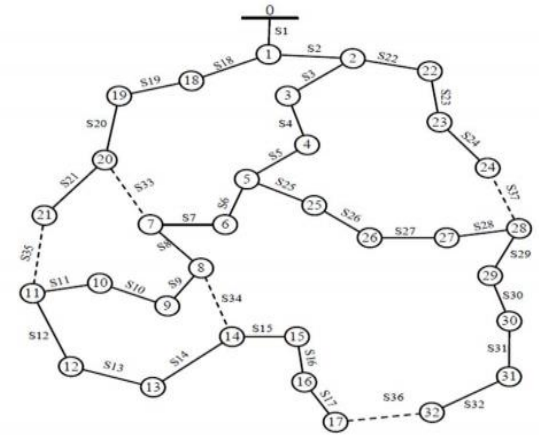

Fig. 2. IEEE 33-bus system single line diagram

This system is consists of 37 bytes, because of the network data, where 0 and 1 translate to opened and closed switch states. The basic case is shown in Table 1 as follows, according to this assumption.

B) Simulation results-Without consideration of DGs and Congestion

The algorithm results in altering the switch states by using the proposed reconfiguration technique in this paper. The switches states have been shown in Table 2.

Table.1.
The basic case of IEEE 33-bus Switches states

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0

Table.2.
Switches states of optimal formation regardless of DGs penetration and congestion problem:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0

As shown, the basic network formation of the standard IEEE system represents an ideal network formation using the creative approach proposed.

Pursuant, 1-32 are closed and 33-37 are opened in simple network formation switches, while a variety of sectionalizing and tie switches have changed status in optimal formation. In optimum formation, opened switches are 7, 9, 14, 32 and 37 respectively. The DLMP contrast between the primary formation of the standard IEEE 33-bus system and the optimum formation gotten by the proposed technique is based on the intended process (Fig.3).

The bars of blue in Fig. 3 shows the DLMPs obtained from the primary formation, while the orange bars indicate the optimum formation of the DLMPs obtained from the intended process. In the first example, the average DLMP is 22.02 $/MWh, while the optimum formation average decreases to 21.31 $/MWh.

It can be seen that DLMP has been decreased in most buses and the overall reduction in DLMP allocated to bus 14 has been reduced. In return for primary value, this reduction is approximately 8 percent and DLMP is lower from 23.13 to 21.42. It should be remembered that this price adjustment is only for 1 hour and has the ability to save145 $ for the customer on bus 14 by extending it to the monthly bill.

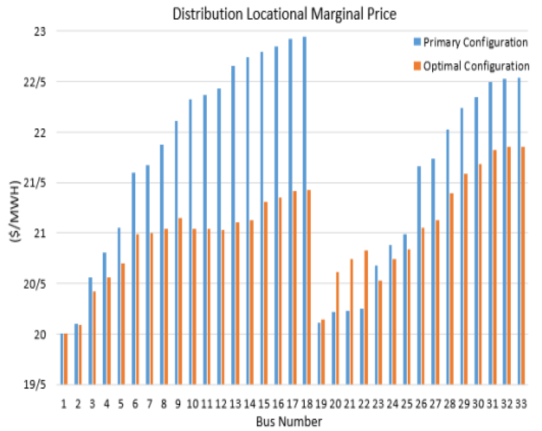

Fig. 3. DLMP ($/MWh) contrast between primary formation and optimal formation using the proposed method

C) *Simulation results-With consideration of DGs and congestion*

In this segment, with the presence of a distribution market operator, distribution network reconfiguration was carried out. Considering the advent of distributed generation as a new approach to marginalizing generations and loads and the rising rate of installed microgrids and other sensitive loads in the distribution network, both the distribution market and the transmission market need to be developed.

These markets should be able to handle the issue of congestion and make emergency decisions, in addition to the duty of conducting market settlement and clearing. Another source of generation has been shown to be important to add to the market process in order to assess the effect of distributed generation and congestion problems in the competitive distribution market. It should also be pointed out that, similar to real networks, the ability of the line must be reduced.

According to the regular IEEE 33-bus system radial formation, two other generators were situated at bus 14 and 29 in this part of the simulations, which are buses with suitable availability. It was also believed that the generator number 2 at bus 14 will generate power at the constant price of 25 $/MWh and that the bus generator 29 intended to submit the price of 30 $/MWh as its constant bid. It should be noted that the capacity of all lines has been limited to 2 MVA.

A contrast between the operational cost of the primary formation and the optimum formation was carried out to specify the value of using DLMP for distribution network reconfiguration. Switches states of the optimum formation with regard to the problem of DG penetration and congestion were brought down based on Table 3.

Represents the optimum design of the network, using the revolutionary approach suggested with DGs and congestion issues in mind. As means that opened switches are switches with 4, 20, 26, 33 and 34 numbers in optimum formation for minimizing the cost of network service, considering congestion problems. Just in Fig. (4) As previously stated, the blue bars show the DLMPs obtained from the primary formation and the orange bars show the optimal formation of the DLMPs obtained from the intended process. The average DLMP in the primary case is 27.03 $/MWh, according to this calculation, while the average DLMP in the optimal case was decreased by 25.04 $/MWh. In this scenario, reconfiguration of the distribution network will lead to a reduction in DLMPs of 2.13 $/MWh on average.

Up to now, the reconfiguration of the distribution network has been aimed at minimizing the cost of failure while employing the optimum formation with the least active loss. It is a logical decision to find the minimum loss formation, as total costs consist of the three terms listed above. If distribution line capacity is not limited and the network is energized from a single bus, marginal cost of electricity and marginal cost of congestion will be reduced.

Table.3.
Switches states of the optimum formation with regard to the problem of DG penetration and congestion

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1

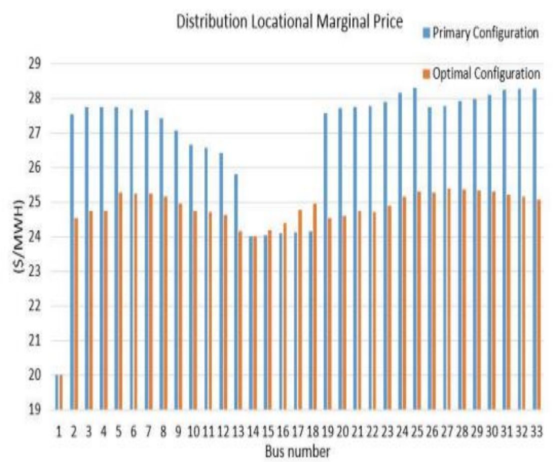

Fig. 4. DLMP ($/MWh) comparison between primary formation and optimal formation with consideration of DGs and congestion

But there are some DGs in real modern distribution networks which Power is being sold and, on the other hand, charging electric vehicles would create the issue of congestion at the level of distribution. The proposed method provides a modern approach to solving the reconfiguration of the distribution network using the DLMP definition, which can take into account new aspects of ongoing distribution networks.

5. Conclusion

Used by the distribution system operator (DSO), conventional distribution network reconfiguration strategies usually seek to minimize the cost of power loss. This paper has introduced a new approach for discovery optimal reconfiguration in the distribution network using PSO with the application of DLMP. This plan has the capacity to take into account the latest facets of the future delivery network, i.e. The contribution of DGs to the electricity distribution markets and the issue of congestion emerged due to the entry of massive, responsible loads known as electric vehicles. First, in the absence of consideration of DGs and congestion, the simulation results obtained were checked by comparing them with common and preceding approaches aimed at minimizing power loss. Subsequently, the suggested approach was used to solve the problem of distribution network reconfiguration using the DLMP principle and empirical results showed a substantial decrease in DLMPs with an average reduction of 8 percent in DLMPs using the algorithm presented.

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