Advances in Mathematics: Scientific Journal **9** (2020), no.10, 8143–8151
ISSN: 1857-8365 (printed); 1857-8438 (electronic)
https://doi.org/10.37418/amsj.9.10.44 Spec. Iss. on AOAOCEP-2020

SIMULTANEOUS NETWORK RECONFIGURATION AND PMU PLACEMENT IN THE RADIAL DISTRIBUTION SYSTEM

S. GANESH[1], V. VENGATESAN, JS. RICHARD JIMREEVES, AND B. RAMASUBRAMANIAN

ABSTRACT. In this paper, new method was developed to locate minimum quantity of Phasor Measurement Unit (PMU) and to find optimal configuration in the distribution system. The proposed technology considers that the PMU placement is recognized simultaneously with the network reconfiguration in the radial distribution system for loss reduction and voltage profile improvement. The problem of PMU placement prepared in this paper is solved through the Multi-Objective Based Emperor penguin optimizer (MOEPO). The 33-bus, 69-bus radial distribution system is considered for PMU installation with different distribution network reconfiguration. The tests results proved that proposed MOEPO can generate high superiority solutions with significant loss diminution and voltage profile enhancement.

1. INTRODUCTION

The Electrical Distribution System (EDS) consists mainly of the opening and closing of switches to transform the EDS topology under the normal condition or the fault in the distribution network [1]. This network reconfiguration topology transformation is done through the distribution network radiality method. Under normal conditions, the key plan of the network reconfiguration topology

[1]*corresponding author*

2020 *Mathematics Subject Classification.* 65C10, 65D15.
Key words and phrases. Network Reconfiguration, Phasor Measurement Unit, Emperor penguin optimizer, Loss, Voltage Profile.

transformation is to diminish the power losses in the EDS. The network reconfiguration process can be finding out by three different types of techniques: mathematical programming, heuristics, and meta-heuristics.

However, the meta-heuristic techniques are favored to solve the difficult objective functions like consistency and voltage sags indexes due to its elasticity and easy performances. Some of the meta-heuristic algorithms such as harmony search algorithm, artificial bee colony, and ant colony optimization and are projected for network reconfiguration with the objective of system power loss and voltage profile. Conflicting from transmission systems, distribution systems typically have a meshed topology but work radially to enhance the system efficiency and confirm the power deliver under normal and faulty conditions [2]. Observably, with the placement of distributed generation [3], capacitor [4], and D-STATCOM [5], distribution systems are facing more repeated configuration changes under fault conditions [6]. For that reason, the placement of PMU techniques for distribution systems should assurance the observability of the whole system under various network configurations [7]. Nowadays, Phasor Measurement Unit (PMU) plays a vital role in power system observability, state estimation, wide-area control, and protection in power systems due to its immense advantages. PMU is the most recent highly developed metering device which can give real-time voltage and current synchronization measurements with high accurateness [8]. Most of the above literature separately solved the difficulty of network reconfiguration and PMU installation. Hence the main contributions and novelty of this work are:

- Simultaneous solution of PMU placement and network reconfiguration for power loss diminution and voltage profile enhancement.
- Multi-Objective Based Emperor penguin optimizer (MOEPO) formulation to concurrently minimize power loss diminution and voltage profile enhancement.

2. PROBLEM FORMULATION

The typical problem formulation of proposed methodology is defined as solving the problem of network reconfiguration and placement of PMUs problem to decrease the power loss and develop the voltage profile. The objective function of the proposed problem can be denoted as:

$$F(x) = Min\left(\frac{P_{T,loss} + P_{T,loss}^{PMU}}{P_{T,loss}}\right) + Max\left(\frac{n}{\sum_{i=1}^{n} V_i(x)}\right)$$

Subjected to the subsequent constraint,

(1) The installation of PMU are evaluated from the following expressions,

$$PMU = \begin{cases} 1;\text{ PMU is allocated to } b^{th} \text{ bus} \\ 0;\text{ otherwise} \end{cases}$$

(2) Radial constraint,

$$Det(A) = 1(or) - 1(\text{radial network})$$

(3) Voltage constraint,

$$V_{min} \leq \mid V_i \mid \leq V_{max}$$

(4) Current constraint,

$$|I_{i,i+1}| \leq |I_{i,i+1,max}|$$

3. EMPEROR PENGUIN OPTIMIZER (EPO)

Emperor penguin optimizer (EPO) is proposed by Dhiman in the year of 2018. EPO is mimicking by the clustering movement of emperor penguins in the Antarctic. In that proposed algorithm, the temperature value around the cluster is determined, and the method has vector-based equations, even as we determined the each penguin's body temperature and penguin's body heat radiation and then because of space and prettiness each penguin executes the spiral-like progress [9].

All penguins are spread all the way through the environment [10]. First, the location of each penguin and its cost are determined. Then penguins cost are compared with each other. Penguins are constantly moving near a penguin that has a minimum cost of the combination. The cost of the penguin is calculated by the heat intensity and space. Once attraction is finished, a new solution is calculated and updated. All new solutions are arranged and the best solution is elected. For this method, have some rules as projected in flowchart is shown Fig. 1.

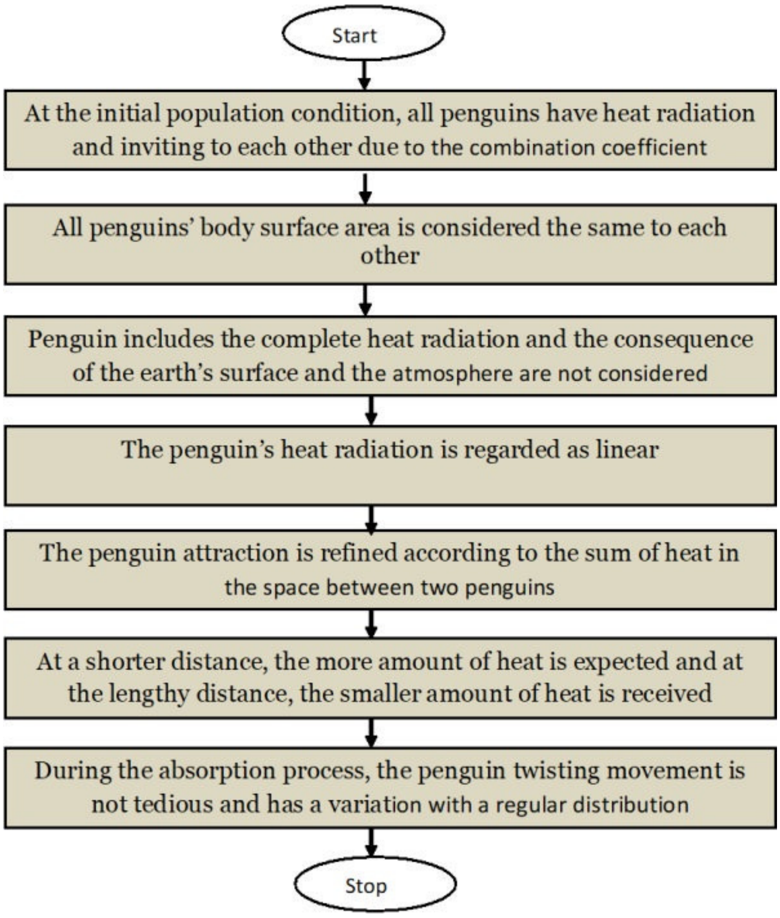

FIGURE 1. Flowchart for EPO algorithm

4. RESULT AND DISCUSSION

The proposed MOEPO algorithm for network reconfiguration and PMU placement for loss reduction and voltage improvement has been tested in the IEEE 33, 69 bus systems. The load and line data for 33, 69 bus system were obtained from Ref. [5].

The parameters settings of the MOEPO used in the tests with the 33, 69 bus systems are: population size = 100; Temperature profile T' = [1,800]; Parameters $\vec{A}$=[-1,1], M=2, f=[2,2], l = [2.5,2.5]; maximum number of generations = 1000; and search agents=100. The performance of the proposed algorithm for network reconfiguration and PMU placement has been tested through five different cases as follows:

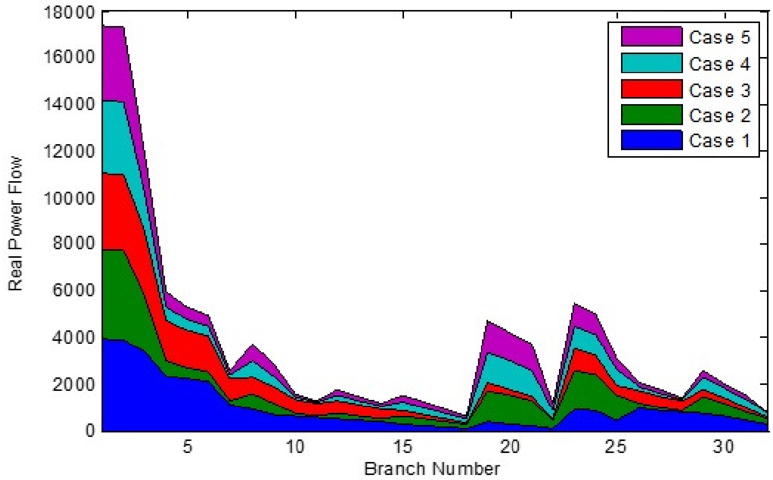

FIGURE 2. Real power flow for 33-bus system

Case 1: Without network reconfiguration and PMU placement.

Case 2: only network reconfiguration of distribution system.

Case 3: only Placement of PMU.

Case 4: PMU placement after reconfiguration network.

Case 5: Simultaneous network reconfiguration and PMU placement.

For 33-bus system, the real and reactive power flow at each branch is shown in Fig. 2 and 3. It is experimental that real and reactive power flow in each branch is reduced in Case 2, 3, 4 and 5 by using the proposed MOEPO approach. From these figures, it is observed that a bus can be relieved from the overloading and made to deliver reliable power supply to the loads.

Table 1 summarizes results of application of the proposed MOEPO for all the five cases of the 33 and 69-bus test system. The total real power demands of 33 and 69 bus systems were 3715 kW and 3802.1 kW respectively. The total reactive power demands of 33 and 69 bus systems were 2300 kVAr and 2694.5 kVAr respectively.

For 33-bus network results from Table 1, it is observed that the base case loss of 202 kW is reduced to 30.9 kW, 48.6 kW, 54 kW and 62.2 kW with respect to the cases II–V using MOEPO algorithm. Moreover, the proposed MOEPO approach gives a considerable enhancement of minimum bus voltage profile

TABLE 1. Performance of the 33-Bus System

System	Parameters	Case 1	Case 2	Case 3	Case 4	Case 5
33-bus	Tie lines	33, 34, 35, 36, 37	7, 14, 9, 33, 28	33, 34, 35, 36, 37	7, 33, 9, 21, 28	7, 33, 9, 22, 28
	Total No. of PMUs	-	-	7	10	11
	PMU Bus No.	-	-	3, 4, 8, 11, 15, 26, 31	2, 4, 8, 10, 12, 17, 24, 25, 29, 31	3, 5, 8, 10, 12, 7, 16, 19, 20, 25, 29
	$P_{T,Loss}$(kW)	202	139.5	103.7	92.9	76.3
	%Loss Reduced	-	30.9	48.6	54	62.2
	V_{min} (p.u) & Bus No.	0.9131 (18)	0.9229 (31)	0.9431 (18)	0.9543 (32)	0.9629 (31)
66-bus	Tie lines	69, 70, 71, 72, 73	69, 70, 11, 53, 61	69, 70, 71, 72, 73	69, 71, 12, 58, 61	69, 70, 14, 54, 61
	Total No. of PMUs	-	-	14	17	21
	PMU Bus No.	-	-	2, 4, 7, 9, 62, 63, 16, 19, 22, 24, 27, 33, 48, 53	2, 5, 11, 19, 62, 65, 22, 28, 29, 32, 38, 41, 49, 53, 55, 59, 60	3, 4, 9, 17, 62, 65, 23, 27, 29, 34, 39, 41, 49, 54, 55, 59, 60, 63, 64, 66, 69
	$P_{T,Loss}$(kW)	225	102.5	96.3	88.7	79.2
	%Loss Reduced	-	54.4	57.2	60.5	64.8
	V_{min} (p.u) & Bus No.	0.9092 (65)	0.9287 (66)	0.9411 (65)	0.9532 (61)	0.9677 (69)

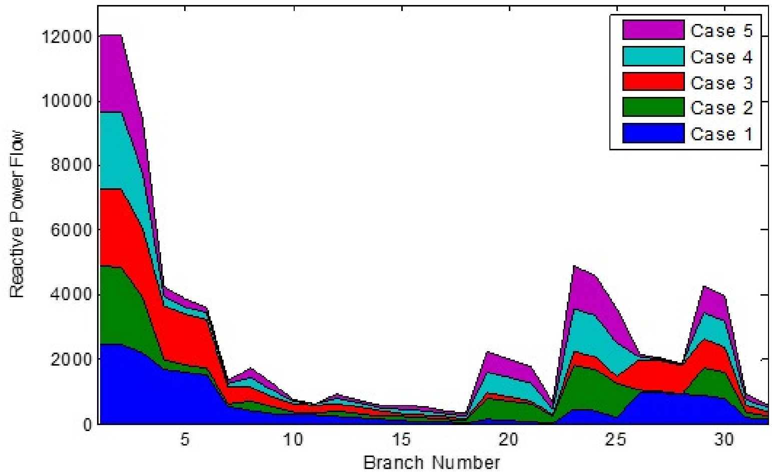

FIGURE 3. Reactive power flow for 33-bus system

with case V as compared with other cases. For 69-bus system results from Table 1, it is noticed that the base case loss of 225 kW is reduced to 54.4 kW, 57.2 kW, 60.5 kW and 64.8 kW with respect to the cases II–V using MOEPO algorithm. It is noticed that case V gives better loss reduction with enhanced bus voltage profile as compared with all other cases. While the power flow path is optimized in case V by optimal PMU placement and network reconfiguration for better power loss drop is attained.

Real power losses of each branch for all five cases of 33 and 69-bus network are represented in Fig. 4 and Fig. 5. Best loss reduction was justifiably achieved with 11 PMUs and 21 PMUs for 33, 69-bus networks respectively. Furthermore, case 5 results to be a better choice than other cases in the context of loss reduction.

5. CONCLUSION

This paper achieved an optimization topology for simultaneous network reconfiguration and PMU installation in a radial distribution network. The proposed objectives have been attained using a multi-objective formulation that minimizes the power losses and maximizes the voltage profile. This multi-objective formulation was solved using a meta-heuristic technique based on the MOEPO. The results achieved with the 33, 69-bus system demonstrate that the effective MOEPO technique was attained with a smaller amount power loss

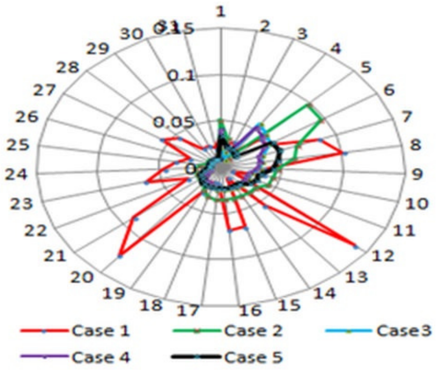

FIGURE 4. Real power loss of 33-bus system

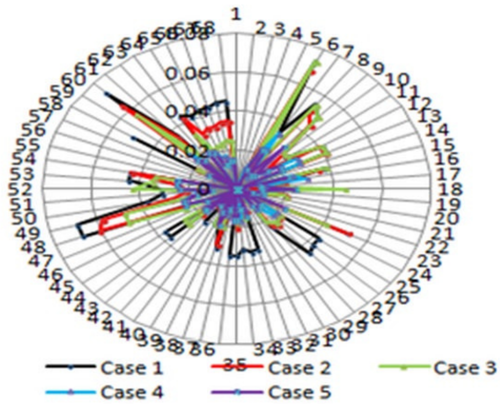

FIGURE 5. Real power loss of 69-bus system

and a minimum number of PMUs for simultaneous network reconfiguration and PMU placement. The simulation results of the developed MOEPO confirm that this technology is able to give better results for small as well as large-scale distributed systems.

REFERENCES

[1] R.J. SARFI, M.M.A. SALAMA, A.Y. CHIKHANI: *A Survey of the State of the Art in Distribution System Reconfiguration for System Loss Reduction*, Electr. Power. Syst. Res., **31**(1) (1994), 61–70.

[2] Q. QI, J. WU, C. LONG: *Multi-Objective Operation Optimization Of An Electrical Distribution Network With Soft Open Point*, Appl. Energy, **208** (2017), 734–744.

[3] G. SELVARAJ, K. RAJANGAM: *Multi-Objective Grey Wolf Optimizer Algorithm for Combination of Network Reconfiguration and D-STATCOM Allocation In Distribution System*, Int. Trans. Electr. Energ. Syst., (2019), e12100.

[4] S. GANESH, R. KANIMOZHI: *Multi Objective Approach For Capacitor Placement based on Load Balancing Index in Radial Distribution System*, J. Comp. Theo. Nanosci., **653**(204) (2018), 368–375.

[5] S. GANESH, R. KANIMOZHI: *Meta-Heuristic Technique for Network Reconfiguration in Distribution System with Photovoltaic and D-STATCOM*, IET Gene. Trans. Dist., **12**(20) (2018), 4524–4535.

[6] H. JI, C. WANG, P. LI, G. SONG, H. YU, J. WU: *Quantified Analysis Method for Operational Flexibility of Active Distribution Networks with High Penetration of Distributed Generators*, Appl. Energy, **239** (2019), 706–714.

[7] H. JI, C. WANG, P. LI, J. ZHAO, G. SONG, J. WU: *Quantified Flexibility Evaluation of Soft Open Points to Improve Distributed Generator Penetration in Active Distribution Networks based on Difference-Of-Convex Programming*, Appl. Energy, **218** (2018), 338–348.

[8] B. GOU, R. G. KAVASSERI: *Unified PMU Placement for Observability and Bad Data Detection in State Estimation*, IEEE Trans. Power. Syst., **29**(6) (2014), 2573–2580.

[9] G. DHIMAN, V. KUMARA: *Emperor Penguin Optimizer: A Bio-inspired Algorithm for Engineering Problems*, Know Sys., **159** (2018), 20–50.

[10] M. PREMKUMAR, R. SOWMYA: *An Effective Maximum Power Point Tracker for Partially Shaded Solar Photovoltaic Systems*, Energy Rep. **5** (2019), 1445–1462.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SRM TRP ENGINEERING COLLEGE
MANNACHANALLUR TALUK, IRUNGALUR, TAMIL NADU 621105, INDIA
Email address: gauti.ganeshs@gmail.com

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SRM TRP ENGINEERING COLLEGE
MANNACHANALLUR TALUK, IRUNGALUR, TAMIL NADU 621105, INDIA
Email address: vengatesanv@gmail.com

DEPARTMENT OF INFORMATION TECHNOLOGY
EASWARI ENGINEERING COLLEGE
RAMAPURAM, CHENNAI, TAMIL NADU 600089, INDIA
Email address: richardjimreeveseec@gmail.com

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
SRM TRP ENGINEERING COLLEGE
MANNACHANALLUR TALUK, IRUNGALUR, TAMIL NADU 621105, INDIA
Email address: ramatech87@gmail.com