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Planning and Operation Enhanced Voltage Profile by Using Distributed Generators Installation in Distribution System with Feeder Reconfiguration

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***Abstract*—This paper presents the planning and operation enhanced voltage profile by using distributed generators installation in distribution system with feeder reconfiguration. The key factor that enhances the performance of the power distribution system is voltage. The objective of paper is enhanced voltage profile in distribution system, tested in 69 bus distribution system model with MATLAB program. The tested results found that distributed generation according to the conditions of this paper can enhance voltage in distribution system.**

Keywords—Voltage Profile, Distributed Generator, Distribution System, Feeder Reconfiguration

I. INTRODUCTION

The distribution system reliability is an essential factor for this operation because it is the last terminal connection point between the power grid and the consumer. Feeder reconfiguration is a technique that corrects system interruptions and allows timely power transmission by minimizing downtime resulting from switch status changes. The power supply pattern remains the same but changes the structure of the power distribution system [1].

Distributed generation (DG) is small technology to generate electricity closer to user. DG has several uses and sometimes renewable energy. Examples of distributed generation for instance solar, wind turbine and hydropower. Distributed generation are another alternative to fix the distribution system. Type of distributed generation as shown in Fig. 1. [2]

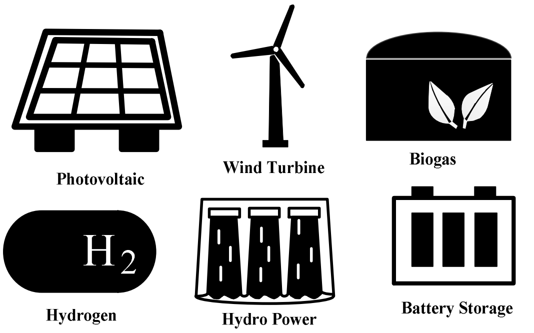

Fig. 1. Type of distributed generation.

In 2009 [3], there was a study on Tabu search for optimal feeder reconfiguration and distributed generators in a distribution system, tested in distribution system 69 bus with MATLAB program. In 2009 [4], there was a study of a fuzzy multiobjective and Tabu search to optimal feeder reconfiguration with distributed generators in a distribution system, tested in distribution system 69 bus with a MATLAB program.

This paper presents a planning and operation enhanced voltage profile by using distributed generators installation in distribution system with feeder reconfiguration. Tested in 69 bus distribution system model with a MATLAB program.

II. FEEDER RECONFIGURATION

Feeder reconfiguration [5] is a system that changes the status of sectionalizing and ties switches. This result in changing the structure of the distribution system. The heavy load feeder has transferred to the light load feeders, to reduce power loss, improve reliability and voltage profile in the distribution system. Schematic diagram of the distribution system as shown in Fig. 2.

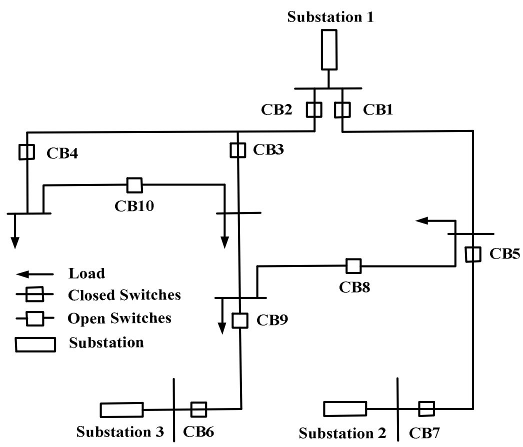

Fig. 2. Schematic diagram of distribution system.

From the Fig. 2. The CB1-CB7 are closed switch and CB8-CB10 are open switch, where CB8 is connects three primary feeders. A loop will occur when closing CB10 [6].

III. PHOTOVOLTAIC

Photovoltaic [7] is one of the methods of generating electricity. The electrical energy produced by this method comes from natural sources such as sunlight. This device can convert sunlight into electricity based on the intensity of solar energy. Therefore this kind of energy is clean, safe, and more sustainable than the other energy source. The conversion of direct current energy (DC) into alternating current energy (AC) can be done by the photovoltaic system, which consists of solar panels and inverter. Schematic diagram of the photovoltaic system as shown in Fig. 3.

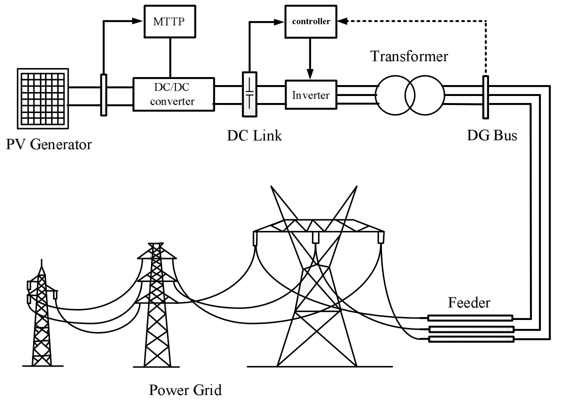

Fig. 3. Schematic diagram of photovoltaic system.

IV. POWER FLOW EQUATION

Single line diagram of feeder shown in Fig. 4. Real power and Reactive power between buses calculated in the equation (1)-(2) [8].

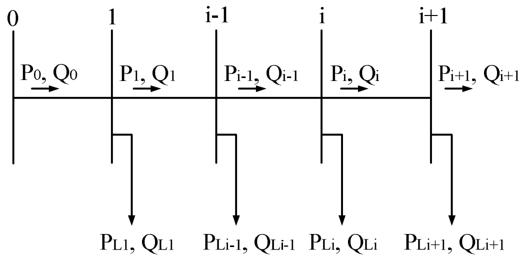

Fig. 4. Single line diagram of feeder.

$$P_{i+1} = P_i - P_{Li+1} - R_{i,j+1}\left[\frac{(P_i^2 + Q_i^2)}{|V_i|^2}\right] \tag{1}$$

$$Q_{i+1} = Q_i - Q_{Li+1} - X_{i,j+1}\left[\frac{(P_i^2 + Q_i^2)}{|V_i|^2}\right] \tag{2}$$

Equation (3) shows the formula to calculate power loss of the line connection from bus i to bus i+1.

$$P_{Loss}(i, i+1) = R_{i,j+1}\left[\frac{(P_i^2 + Q_i^2)}{|V_i|^2}\right] \tag{3}$$

Where P_i, Q_i is real and reactive power at bus i
V_i is voltage at bus i
$R_{i,i+1}$ is line resistance between bus i and i+1
$X_{i,i+1}$ is line reactance between bus i and i+1

V. CASESTUDY

For this study, 69 bus distribution system model with DGs installation was used to enhance the voltage profile as shown in Fig. 5. Each branch in the system has a separate switch to reconfigure. Load data in the Table AI and branch data in the Table AII [9]. Sectionalizing switch (close switch) is a switch number from 1 to 68. A tie switch (open switch) is a switch from number 69 to 73. The system total load is 3,801.89 kW and 2,694.10 kVAr. The system base is 100 MVA, and the voltage base is 12.66 kV.

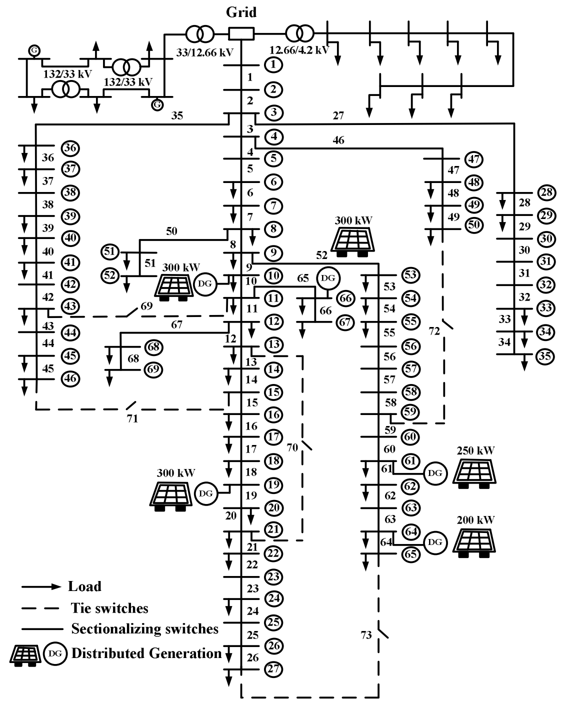

Fig. 5. Distribution system 69 bus.

Five cases were tested as follows:

Case 1: Base case (no feeder reconfiguration and DG installation).
Case 2: Feeder reconfiguration and installation 4 DGs, total capacity is 1,050 kW.
Case 3: Feeder reconfiguration and installation 5 DGs, total capacity is 1,900 kW.
Case 4: Feeder reconfiguration and installation 6 DGs, total capacity is 1,550 kW.
Case 5: Feeder reconfiguration and installation 10 DGs, total capacity is 3,200 kW.

VI. Result

Capacity and location of DGs as shown in Table I. Result enhanced voltage profile by using distributed generators installation in distribution system with feeder reconfiguration as shown in Table II.

TABLE I. Capacity and Location of DGs

Case	Number of DGs	Location of DGs	Capacity (kW)	Total capacity (kW)
1	-	-	-	-
2	4	11, 27, 61, 65	400, 100, 250, 300	1,050
3	5	27, 47, 49, 61, 63	150, 400, 450, 550, 350	1,900
4	6	10, 19, 27, 61, 64, 66	300, 300, 200, 250, 200, 300	1,550
5	10	4, 9, 22, 27, 47, 50, 58, 61, 63, 64	300, 300, 300, 300, 300, 300, 350, 400, 250, 400	3,200

TABLE II. Result Enhanced Voltage Profile by Using Distributed Generators Installation in Distribution System with Feeder Reconfiguration

	Case 1	Case 2	Case 3	Case 4	Case 5
Power loss (kW)	224.56	91.78	159.31	103.10	120.40
Percent Power loss	-	59.12	29.05	54.08	46.38
Minimum voltage	65 (0.90 p.u.)	62 (0.95 p.u.)	61 (0.95 p.u.)	61 (0.95 p.u.)	61 (0.95 p.u.)
Sectionalizing switch to be open	-	16, 36, 54	35, 46	9, 14, 18, 52	3
Tie switch to be closed	-	71, 72, 73	69, 71, 72, 73	70, 71, 72, 73	69, 71, 72, 73

The results voltage profile for case 2, 3, 4 and 5 as shown in Fig. 6, 7, 8 and 9.

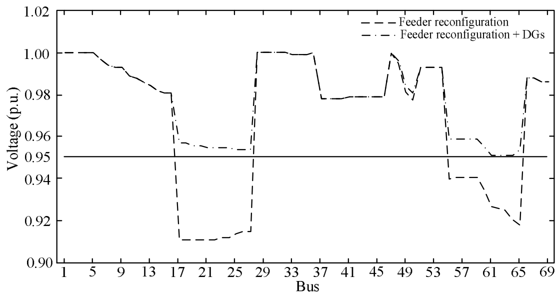

Fig. 6. Voltage profile of case 2 feeder reconfiguration and installation 3 DGs, total capacity is 1,050 kW.

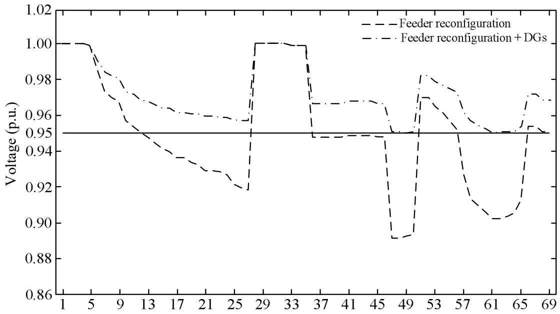

Fig. 7. Voltage profile of case 3 feeder reconfiguration and installation 5 DGs, total capacity is 1,900 kW.

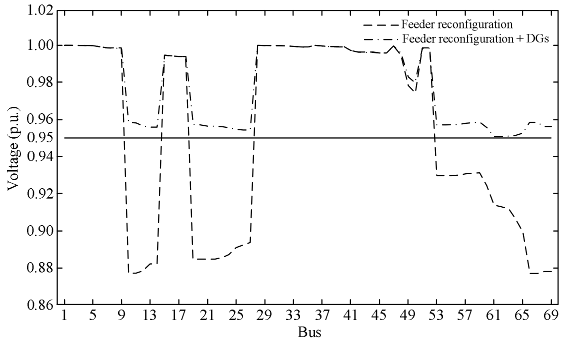

Fig. 8. Voltage profile of case 4 feeder reconfiguration and installation 6 DGs, total capacity is 1,550 kW.

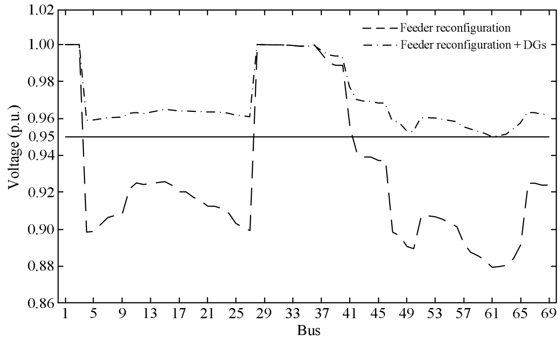

Fig. 9. Voltage profile of case 5 feeder reconfiguration and installation 10 DGs, total capacity is 3,200 kW.

From Fig. 6, 7, 8 and 9. Voltage profile of all buses in the distribution system was enhanced to the standard (0.95-1.05 p.u.). Case 2: feeder reconfiguration and installation 4 DGs, total capacity is 1,050 kW can enhance voltage to the standard and maximum power loss reduction.

VII. Conclusion

This paper presents planning and operation enhanced voltage profile by using distributed generators installation in distribution system with feeder reconfiguration. Which has performed five case tested follow, case 1: base case (no feeder reconfiguration and DG installation), case 2: feeder reconfiguration and installation 4 DGs, total capacity is 1,050 kW, case 3: feeder reconfiguration and installation 5 DGs, total capacity is 1,900 kW, case 4: feeder reconfiguration and installation 6 DGs, total capacity is 1,550 kW and case 5: feeder reconfiguration and installation 10 DGs, total capacity is 3,200 kW. The tested results found that distributed generation according to the conditions of this paper can enhance voltage in distribution system.

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References

[1] M. A. Kashem, V. Ganapathy, and G. B. Jasmon, "Network reconfiguration for enhancement of voltage stability in distribution networks," IEEE Proceedings - Generation, Transmission and Distribution, vol.147, no.3, pp.171-175, May 2000.

[2] P. Ngamprasert, S. Woothipatanapan, P. Wannakarn, and N. Rugthaicharoencheep, "Improvement for Voltage Sag with Photovoltaic Performance on Distribution System," IEET - International Electrical Engineering Transactions, vol.6, no.1, pp.28-33, January - June 2020.

[3] N. Rugthaicharoencheep, and S. Sirisumrannukul, "Feeder reconfiguration with dispatchable distributed generators in distribution system by tabu search," 2009 44th International Universities Power Engineering Conference (UPEC), 2009.

[4] N. Rugthaicharoencheep, and S. Sirisumrannukul, "Optimal feeder reconfiguration with distributed generators in distribution system by fuzzy multiobjective and Tabu search," 2009 International Conference on Sustainable Power Generation and Supply, 2009.

[5] T. Lantharthong, and N. Rugthaicharoencheep, "Network Reconfiguration for Load Balancing in Distribution System with Distributed Generation and Capacitor Placement," World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering," vol.6, no.4, pp. 409-414, 2012.

[6] N. Rugthaicharoencheep, and S. Sirisumrannukul, "Feeder Reconfiguration for Loss Reduction in Distribution System with Distributed Generators by Tabu Search," GMSARN International Journal, vol.3, no.2, pp. 47-54, June 2009.

[7] P. Ngamprasert, P. Wannakarn, and N. Rugthaicharoencheep, "Enhance Power Loss in Distribution System Synergy Photovoltaic Power Plant," 2020 International Conference on Power, Energy and Innovations (ICPEI), 2020.

[8] M. Dixit, P. Kundu, and H. R. Jariwala, "Optimal placement of PV array in distribution system for power loss minimization considering feeder reconfiguration," 2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC), 2016.

[9] J. S. Savier, and D. Das, "Impact of Network Reconfiguration on Loss Allocation of Radial Distribution Systems," IEEE Transactions on Power Delivery, vol.22, pp.2473-2480, October 2007.

Appendix

TABLE AI

LOAD DATA OF 69 BUS DISTRIBUTION SYSTEM

Bus Number	P (kW)	Q (kVAr)	Bus Number	P (kW)	Q (kVAr)
6	2.60	2.20	37	26.00	18.55
7	40.40	30.00	39	24.00	17.00
8	75.00	54.00	40	24.00	17.00
9	30.00	22.00	41	1.20	1.00
10	28.00	19.00	43	6.00	4.30
11	145.00	104.00	45	39.22	26.30
12	145.00	104.00	46	39.22	26.30
13	8.00	5.00	48	79.00	56.40
14	8.00	5.50	49	384.70	274.50
14	8.00	5.50	49	384.70	274.50
16	45.50	30.00	50	384.70	274.50
17	60.00	35.00	51	40.50	28.30
18	60.00	35.00	52	3.60	2.70
20	1.00	0.60	53	4.35	3.50
21	114.00	81.00	54	26.40	19.00
22	5.00	3.50	55	24.00	17.20
24	28.00	20.00	59	100.00	72.00
26	14.00	10.00	61	1,244.00	888.00
27	14.00	10.00	62	32.00	23.00
28	26.00	18.60	64	227.00	162.0
29	26.00	18.60	65	59.00	42.00
33	14.00	10.00	66	18.00	13.00
34	19.50	14.00	67	18.00	13.00
35	6.00	4.00	68	28.00	20.00
36	26.00	18.55	69	28.00	20.00

TABLE AII

BRANCH DATA OF 69 BUS DISTRIBUTION SYSTEM

Branch Number	Sending end bus	Receiving end bus	R (Ω)	X (Ω)
1	1	2	0.0005	0.0012
2	2	3	0.0005	0.0012
3	3	4	0.0015	0.0036
4	4	5	0.0251	0.0294
5	5	6	0.3660	0.1864
6	6	7	0.3811	0.1941
7	7	8	0.0922	0.0470
8	8	9	0.0493	0.0251
9	9	10	0.8190	0.2707
10	10	11	0.1872	0.0619
11	11	12	0.7114	0.2351
12	12	13	1.0300	0.3400
13	13	14	1.0440	0.3450
14	14	15	1.0580	0.3496
15	15	16	0.1966	0.0650
16	16	17	0.3744	0.1238
17	17	18	0.0047	0.0016
18	18	19	0.3276	0.1083
19	19	20	0.2106	0.0690
20	20	21	0.3416	0.1129
21	21	22	0.0140	0.0046
22	22	23	0.1591	0.0526
23	23	24	0.3463	0.1145
24	24	25	0.7488	0.2475
25	25	26	0.3089	0.1021
26	26	27	0.1732	0.0572
27	3	28	0.0044	0.0108
28	28	29	0.0640	0.1565
29	29	30	0.3978	0.1315
30	30	31	0.0702	0.0232
31	31	32	0.3510	0.1160
32	32	33	0.8390	0.2816
33	33	34	1.7080	0.5646
34	34	35	1.4740	0.4873
35	3	36	0.0044	0.0108
36	36	37	0.0640	0.1565
37	37	38	0.1053	0.1230
38	38	39	0.0304	0.0355
39	39	40	0.0018	0.0021
40	40	41	0.7283	0.8509
41	41	42	0.3100	0.3623
42	42	43	0.0410	0.0478
43	43	44	0.0092	0.0116
44	44	45	0.1089	0.1373
45	45	46	0.0009	0.0012
46	4	47	0.0034	0.0084
47	47	48	0.0851	0.2083
48	48	49	0.2898	0.7091
49	49	50	0.0822	0.2011
50	8	51	0.0928	0.0473
51	51	52	0.3319	0.1114
52	9	53	0.1740	0.0886
53	53	54	0.2030	0.1034
54	54	55	0.2842	0.1447
55	55	56	0.2813	0.1433
56	56	57	1.5900	0.5337
57	57	58	0.7837	0.2630
58	58	59	0.3042	0.1006
59	59	60	0.3861	0.1172
60	60	61	0.5075	0.2585
61	61	62	0.0974	0.0496
62	62	63	0.1450	0.0738
63	63	64	0.7105	0.3619
64	64	65	1.0410	0.5302
65	11	66	0.2012	0.0611
66	66	67	0.0047	0.0014
67	12	68	0.7394	0.2444
68	68	69	0.0047	0.0016
Tie Line				
69	11	43	0.5000	0.5000
70	13	21	0.5000	0.5000
71	15	46	1.0000	0.5000
72	50	59	2.0000	1.0000
73	27	65	1.0000	0.5000