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Optimization Sizing and Placement Distributed Generation with Determination Network Reconfiguration and Capacitor Bank Simultaneously to Maximize Active Power Output of Distributed Generation Using Genetic Algorithm Method

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ABSTRACT

The demand for electricity continues to increase in line with the growth of population but it is not matched with adequate power generation. Distributed Generation (DG) is one of the solutions to increase the availability of electrical energy which is able to accommodate the development. DG is able to supply additional active power in distribution network but less precise placement may result in less optimal active power output of DG. Therefore, this paper presents reconfiguration of the network, DG and capacitor optimal placement using Genetic Algorithm (GA) either sequentially or simultaneously to be tested on a modified IEEE 69 buses radial distribution system. The test showed that the optimization techniques in network reconfiguration, DG, and capacitors placement simultaneously are able to increase the bus voltage profile to satisfy the constraint. The minimum voltage limit on the optimization is 0.98537pu.

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OPTIMIZATION SIZING AND PLACEMENT DISTRIBUTED GENERATION WITH DETERMINATION NETWORK RECONFIGURATION AND CAPACITOR BANK SIMULTANEOUSLY TO MAXIMIZE ACTIVE POWER OUTPUT OF DISTRIBUTED GENERATION USING GENETIC ALGORITHM METHOD

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Abstract

The demand for electricity continues to increase in line with the growth of population but it is not matched with adequate power generation. Distributed Generation (DG) is one of the solutions to increase the availability of electrical energy which is able to accommodate the development. DG is able to supply additional active power in distribution network but less precise placement may result in less optimal active power output of DG. Therefore, this paper presents reconfiguration of the network, DG and capacitor optimal placement using Genetic Algorithm (GA) either sequentially or simultaneously to be tested on a modified IEEE 69 buses radial distribution system. The test showed that the optimization techniques in network reconfiguration, DG, and capacitors placement simultaneously are able to increase the bus voltage profile to satisfy the constraint. The minimum voltage limit on the optimization is 0.98537pu.

Keywords: *Active Power, network reconfiguration, the placement of Distributed Generation (DG), capacitor placement and Genetic Algorithm (GA).*

1. Introduction

Society interest about clean and eco-friendly renewable energy has caused distributed generation technology being the focus of many researches lately. The growing of electricity demand and the complexity of distribution system raise system losses with poor voltage regulation. According to the research, the losses in distribution system could reach nearly 10 – 13 % of generated total power. This fact leads to increasing energy cost and poor voltage profile. The commonly used method of voltage stability and power drop in the distribution system are network reconfiguration, DG and capacitor placement. The DG itself basically a power generation which is spread and connected to the main distribution network. The spread power generation is

commonly renewable energy such as wind turbine, micro hydro, and solar photovoltaic (PV). Thus, each unit of distributed generation is not always able to supply power to the main grid continuously. Therefore, a DG unit status is different with one another in the certain time. Network reconfiguration, DG and capacitor placement can maximizing profit and reduce the loss of power system.

Distributed generation is a small sized power generation (commonly in several KW until tens MW). The DG which is not part of the main generation is often located near the load. The use of DG increases since its important role in the power supply. DG utilization has brought some benefits related to its high efficiency, small size, modular capability, and close location with the energy source [1].

In previous research, the effect of DG placement towards power losses and network reliability is studied using Genetic Algorithm. In this paper, Genetic Algorithm is used to determine the location of DG and capacitor as well as network reconfiguration on modified IEEE 69 buses. Optimization of DG sizing and location, as well as a capacitor, are done under bus voltage constraint. Under this constraint, DG and capacitor are located on the certain bus without exceeding the maximum and minimum voltage limit. In [3], network reconfiguration, DG and capacitor placement which is done simultaneously could reduce power losses and improve bus voltage. This method has better result compared to separately applying network reconfiguration, DG and capacitor placement.

2. Literature Review

The generally used distribution network is the radial system. This system has a simple form and low investment cost meanwhile its service quality is relatively poor. In several past years, electricity industry has changed significantly in the distribution system, mainly because of incremental distributed generation technology application. Distributed Generation (DG) is defined as decentralization of power generation by placing smaller generation unit which is closer to the load. The effect of DG placement in the system depends on location and size of DG. Therefore, this paper focuses on the examination of several cases using an effective method to perform network reconfiguration as well as DG and capacitor optimal placement [4], [5].

A. Radial Distribution System

Radial system is commonly used in the distribution system. In this system, the line is drawn radially from a source point and branched out to load point. Thus, the form of the system seems like tree branches with the main line connected to

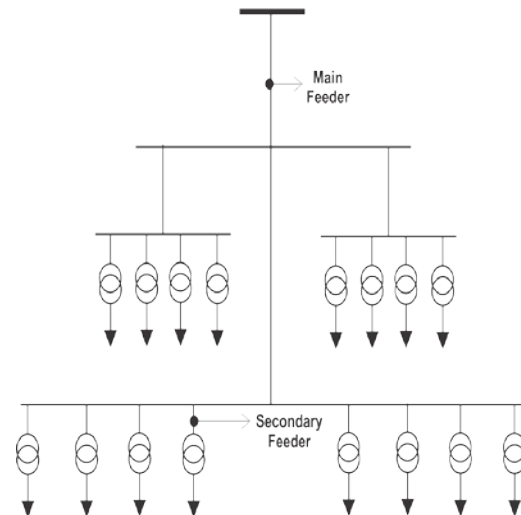


Figure 1. Radial Distribution System

the smaller circuit towards the load. The topology is shown in Figure 1.

The advantages of using radial distribution system are its simple topology and low investment cost. Meanwhile, the weakness of this system is relatively poor service quality caused by high losses and voltage drop. Furthermore, the continuity of power distribution is less reliable. In this system, CB, sectionalized, recloser and other load switch are used to localize fault. This system has a little modification, such as tree type radial system, a radial system with tie-switch, a radial system with load center, and radial system with phase-distribution.

B. Network Reconfiguration

Network reconfiguration is one of the optimization technique in the distribution system. In order to reconfigure the network, tie switch and the sectionalizing switch is opened. The network reconfiguration increases the network operation specifically leading to voltage and power quality improvement. Thus, the operation of distribution system can be done with minimum cost.

Optimization searching method can be used to obtain and determine tie switch and sectionalizing switch status. Currently, many methods have been used in

optimization of reconfiguration, such as PSO, BPSO, GA, and so on.

C. Placement & Sizing Capacitor

According to reference [3], one of the methods to regulate and improve bus voltage is placing paralleled capacitor on distribution busses along a line or between substation and load. Basically, the capacitor is used to produce reactive power in the mounting point. The capacitor can be connected permanently, however for voltage regulation capacitor can be removed to satisfy load dynamics.

Placing capacitor parallel with lagging loads causes the capacitor to behave as a source for supplying a part or all of the reactive power needed by loads. Therefore, the capacitor can be used to reduce current flowing towards loads and decrease voltage drop. Generally, the amount of reactive power and price per unit can be taken into notice in capacitor placement.

D. Placement & Sizing Distributed Generation

Distributed Generation (DG) is small power generation placed close to the load point. DG has the potential to be used for reliability improvement either directly or indirectly. By placing DG, local voltage level can be increased and blackout can be prevented.

DG has several types of forms and modular capability, such as micro hydro, photovoltaic, wind generation and diesel machine as well as battery. Generation capacity of DG could be classified into several categories as shown in Table 1.

Table1. Distributed Generation (DG) Classification based on Generation Capacity

DG Type	Generation Capacity
Micro DG	1 Watt – 5Kw
Small DG	5kW – 5MW
Medium DG	5MW – 50 MW
Large DG	50MW – 300 MW

E. Genetic Algorithm

Genetic Algorithm method (GA) utilizes natural selection process as knows

as evolution process. In the evolution process, individual continuous experience gen mutation to adapt to the environment and only the best individuals could survive.

This method can help solving problems in power system. Generally, the coding is done in binary to arrange a string which forms gens composed chromosome. The solution and best fitness are searched according to desired objective function. The parameter for this methods is a generation, pop size, crossover probability, and mutation. Random generation will be chosen by the genetic operation (selection, crossover, and mutation). The operation result will be evaluated based on objective function, thus the chromosomes used in the next iteration are obtained to perform other iteration.

3. Research Methods

A. IEEE 69 Buses Radial Distribution System

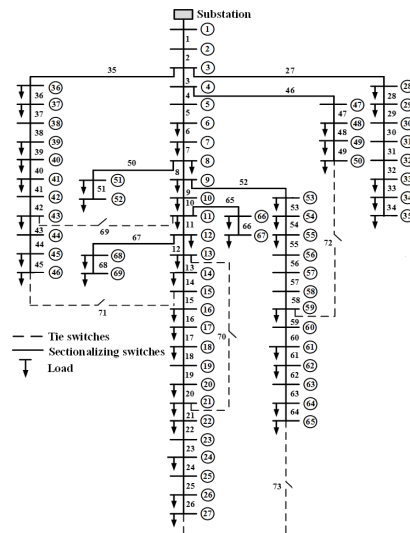


Figure 2. IEEE 69 Bus Single line diagram

IEEE 69 Buses with 5 tie switches is used as a plan in this works. The total amount of active and reactive power is 5,55 MW and 3,96 Mvar. Figure 2 shows the single line diagram of modified IEEE69 Bus.

B. Study Case

In this works, several cases have been conducted to evaluate each

optimization technique and learn its effect toward reactive power output of DG. The conducted study cases are :

a) Modified IEEE 69 Buses Standard System

This case is performed to obtain bus voltage condition in the system before performing optimization technique

b) Network reconfiguration

In this case, network configuration is performed by closing the tie switches and opening sectionalizing switches however the system topology is kept to be radial.

c) Distributed Generation (DG) Placement

This case is conducted only by placing DG.

d) Distributed Generation (DG) and Capacitor Placement

This case is done by placing capacitor and followed by performing DG placement.

e) Simultaneous Network Reconfiguration and DG Placement

Network reconfiguration and DG placement are done simultaneously

f) Sequential Network Reconfiguration, DG and Capacitor Placement

This case is conducted sequentially. The optimization is performed by placing DG and capacitor first then followed by network reconfiguration.

g) Simultaneous Network Reconfiguration, DG, and capacitor Placement

The optimization of network reconfiguration, DG, and capacitor placement are done simultaneously.

C. Objective function

The objective function is a goal of optimization or the desired result. The objective function and some constraints of this work are maximalizing active power output of DG as written on Equation (1) – (4),

$$\text{Maximize } F(x) = \sum_{i=1}^{N_{DG}} P_{DG_i} \quad (1)$$

Where,

P_{DG} i-th of DG output power

N_{DG} number of DGs placed in the system

Each optimization has a constraint as criteria to determine the solution and fitness. Several constraints in this works are :

Voltage constraint

$$0.95 \text{ pu} \leq V_i \leq 1.05 \text{ pu} \quad (2)$$

Constraint active power injection (P MW) of DG

$$\sum_{i=1}^{N_{DG}} P_{DG_i} \leq \sum_{j=1}^{N_L} P_D(j) \quad (3)$$

Constraint reactive power injection (Q MVar) of capacitor

$$\sum_{i=1}^{N_C} Q_C(i) + \sum_{i=1}^{N_{DG}} Q_{DG}(i) \leq \sum_{j=2}^n Q_D(j) \quad (4)$$

D. Design of Component and GA Parameter

In Genetic Algorithm method, there are several components and parameters which are set based on the problem or desired optimization. The following table shows the design of components and GA parameter to the maximizing active output power of DG in the radial distribution system.

Table 2. Representation of component and GA Parameter to maximizing DG active power

GA	Explanation
Gen	1 and 0 binary code
Chromosome	Group of gens (Consisting of optimization solution) Network Reconfiguration (tie switch and sectionalizing switch status)
	Capacitor (Placing and Sizing reactive power injection) DG (Placing and Sizing active power injection)
Population	The number of Chromosome in a group (the amount of solution) = 50
Objective Function	Optimization Goal (Maximizing DG active output power) $\text{Maximize } F(x) = \sum_{i=1}^{NDG} P_{DGi}$
Max Generation	The number of regeneration or generation result of mating = 100
Crossover	Cross mating (PC = 0.95)
Mutation	Mutation (PM = 0.05)

E. Simultaneous Reconfiguration, Capacitor and DG Placement

Coding binary is conducted based on optimization technique and applied plan (IEEE 69 Buses). The following figure shows binary coding and decoding chromosome.

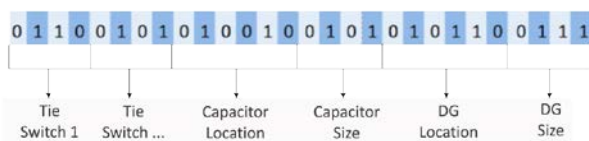
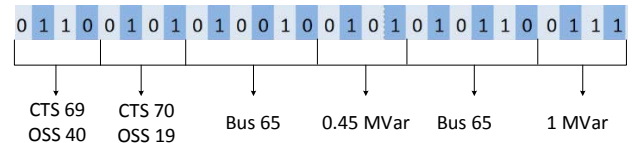


Figure 3. Example of Gen GA

Chromosome in Simultaneous Reconfiguration, Capacitor, and DG Placement



Note : CTS (Close Tie Switch)
OSS (Open Sectionalizing Switch)

Figure 4. Example of Chromosome Decoding in Simultaneous Reconfiguration (tie switch n), 1 capacitor and 1 DG

$$GA = \begin{bmatrix} OS_1^1 OS_1^2 OS_1^3 OS_1^4 OS_1^5 & Cap_1^1 Cap_1^2 Cap_1^3 & DG_1^1 DG_1^2 DG_1^3 \\ OS_2^1 OS_2^2 OS_2^3 OS_2^4 OS_2^5 & Cap_2^1 Cap_2^2 Cap_2^3 & DG_2^1 DG_2^2 DG_2^3 \\ OS_n^1 OS_n^2 OS_n^3 OS_n^4 OS_n^5 & Cap_n^1 Cap_n^2 Cap_n^3 & DG_n^1 DG_n^2 DG_n^3 \end{bmatrix}$$

Rekon Cap Placement DG Placement

Figure 5. Simultaneous Population Optimization of GA

F. Optimization Process Using Genetic Algorithm

Generally, optimization process using Genetic Algorithm (GA) is performed with the following steps:

1. Data and Parameter Reading

The first process is data reading of modified IEEE 69 Buses distribution system in form of line data, bus data, tie switch, and GA parameter as well as another parameter

2. Initiation Load Flow

Initial load flow is done in order to know the initial condition of the system before performing optimization. Thus, initial bus voltage, reactive power (MVar), and active power (MW) of the system can be obtained. The value of that parameter will be used as

standardization value and power injection limit of capacitor and DG.

3. Generating Population

The generated population size depends on the desired optimization, such as 10, 20, 50, and so on. The population is generated randomly which has binary value. Furthermore, Ns-bit from each chromosome is set based on the desired case.

4. Decoding Chromosome

All chromosome will be parsed based on conducted case. Later, all chromosome in population will be decoded to obtain an initial solution.

5. Evolution

In this process, random selection, crossover, and mutation are conducted to obtain offspring. The evolution process will be repeated until the determined generation is reached.

6. Evaluation

The offspring which experience genetic mutation from the parents will be decoded in order to obtain a solution. The solution will be applied in modified IEEE 69 Bus system before conducting Load Flow. From load flow result, voltage minimum limit can be obtained and will be saved in fitness 1.

7. Best Fitness

After evaluation, the selection of individual which has the best fitness is conducted based on constraints. Thus, the selected individual can satisfy the criteria or constraints and has the best fitness. This individual has a solution from optimization case.

4. Analysis & Results

This part presents the result of simulation and analysis using the genetic algorithm as well as forward – backward load flow analysis on distribution system 69 buses IEEE standard. This work is divided in several cases :

Case A : existing condition analysis (without optimization and conditioning system)

Case B : reconfiguration only

Case C : DG placement

Case D : DG and capacitor placement

Case E : reconfiguration and DG placement

Case F : reconfiguration, DG, and capacitor placement sequentially

Case G : reconfiguration, DG, and capacitor placement simultaneously

The result from simulation and analysis will be compared with all of the cases to obtain the best case. In this simulation, the used DG and capacitor are three units. DGs are set to supply active power (P) meanwhile the capacitor supplies reactive power (Q). In this paper, the radial distribution system is applied on 69 buses system IEEE standard. The topology of the system is shown in Figure 2.

Simulation and analysis result :

The following Table 3. is optimization result case A until case G.

In the case of A, the result shows that there are many under voltage on several buses and the worst voltage is 0.86354 p.u. Case B (conditioning using reconfiguration) changes topology of network distribution on the system without DG and capacitor placement, the result for case B still obtains several under voltage bus condition, but voltage value is higher than case A. Case C (conditioning using DG placement), there are 3 installed DG which capacity 0.9322 MW for DG 1, 0.0632 MW, for DG 2 and 2.1488 MW for DG 3. Where the power output of each DG will be optimized by Genetic Algorithm (GA) method. For the case D, the system will be added and installed capacitors with capacity 0.1725 MVar for Capacitor 1, 1.2798 MVar for Capacitor 2, 1.8012 MVar for Capacitor 3. Similar to the case C, using Genetic Algorithm (GA) method to determine that location and size DG and

capacitor. Case E (reconfiguration of the network and the installation of DG simultaneously), network reconfiguration and installation of DG performed simultaneously. Reconfiguration of the network in the condition closed or open on tie switch and sectionalizing switches, DG installed three units with capacity 0.237 MW for DG1, 1.6274 MW for DG2, 1.2798 MW for DG3. Case F and G (reconfiguration of the network, installation of capacitors DG and both sequentially or simultaneously). For the location determination, DG and capacitor of case F and G are same. As for the case G, DG and capacitors are installed each DG with capacity 0.0632 MW for unit DG1, 0.5846 MW for unit DG2, 2.3226 MW for unit DG3 and 0.6785 MVar for unit capacitor1, 0.1725 MVar for unit capacitor2, 1.4375 MVar for unit capacitor3 with optimization using Genetic Algorithm (GA) is able to produce the best solution, whether it generates the corresponding bus voltage constraint or as the allowable limits and generates maximum active power of each DG.

DG and capacitor placement and network reconfiguration either sequentially or simultaneously have a difference in search results and best fitness solution, but simultaneous techniques are better than the sequential techniques. Due to the simultaneous optimization has more variation possibility of incorporation than sequential techniques, can be observed in Figure 3 and Figure 4.

5. Discussion & Conclusion

On the basis of the system, there is a bus under voltage condition. With the installation of DG and capacitors as well as the reconfiguration of the network using genetic algorithm obtained improvements bus voltage.

Placement 3 DG units on bus 22, 58, 63 and 69 produce a maximum active power output till 3.14 MW.

Table 3. Optimization result case A - F

Case	Comparative Study Of Different Case Studies	
Base Case (Case A)	Min.Voltage (p.u)	0.86354
	Max.Voltage (p.u)	1
	Bus Worst	65
Only Reconfiguration (Case B)	Close Tie Switch	71, 72, 73
	Open Sectionilizing S	12, 57, 64
	Min.Voltage (p.u)	0.92682
	Max.Voltage (p.u)	1
	Bus Worst	64
Only DG Placement (Case C)	Min.Voltage (p.u)	0.954052
	Max.Voltage (p.u)	1
	Bus Worst	27
DG, Cap Placement (Case D)	Min.Voltage (p.u)	0.9677
	Max.Voltage (p.u)	1
	Bus Worst	61
Reconfiguration with Simultaneously DG (Case E)	Close Tie Switch	69, 70, 72, 73
	Open Sectionilizing S	18, 42, 57, 61
	Min.Voltage (p.u)	0.96314
	Max.Voltage (p.u)	1
	Bus Worst	61
DG,Cap with Recon (Case F)	Close Tie Switch	71, 72
	Open Sectionilizing S	13, 56
	Min.Voltage (p.u)	0.97973
	Max.Voltage (p.u)	1
	Bus Worst	61
DG,Cap with Recon Simultan (Case G)	Close Tie Switch	71, 72, 73
	Open Sectionilizing S	12, 25, 53
	Min.Voltage (p.u)	0.98274
	Max.Voltage (p.u)	1.013
	Bus Worst	24, 25

Placement 3 DG units and capacitors, able to increase the bus voltage. Likewise with the network reconfiguration and placement 3 DG units sequentially. The voltage value still satisfies the constraint.

Reconfiguration, DG placement, and capacitors, able to increase significantly the bus voltage with merge the three techniques, and it is the most optimal technique. Especially it for which simultaneously.

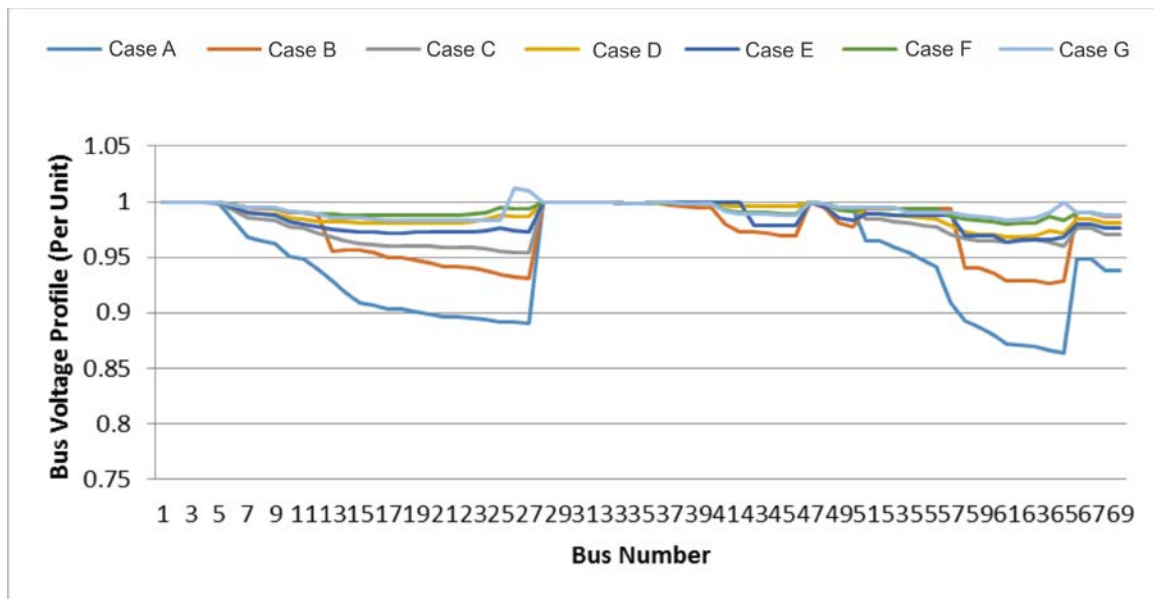


Figure 3. Comparison Voltage Profile each case

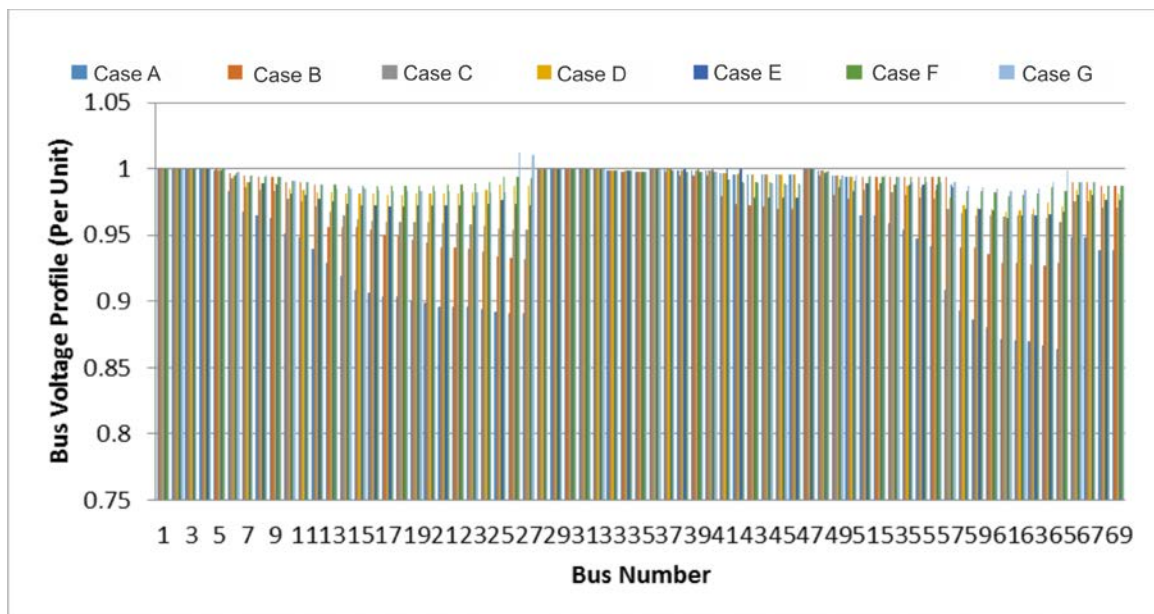


Figure 4. Comparison Voltage Profile each bus and case

The difference in technique sequentially and simultaneously is the manner of the optimization process method. Optimization is performed per-sequential optimization techniques meanwhile simultaneous performed concurrently.

Genetic Algorithm (GA) was able to produce an optimal solution to determine the place and size DG active power output in order to obtain maximum DG. Likewise

with reconfiguration network and capacitor placement.

6. Acknowledgment

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APPENDIX

TABLE AI

LOAD DATA OF 69-BUS DISTRIBUTION SYSTEM

Bus Number	P _L (kW)	Q _L (kVAr)	Bus Number	P _L (kW)	Q _L (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	30,00	21,50
11	145,00	104,00	45	39,22	26,30
12	145,00	104,00	46	195,00	131,50
13	40,00	25,00	48	79,00	56,40
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	570,00	405,00	54	26,40	19,00
22	5,00	3,50	55	24,00	17,20
24	28,00	20,00	59	500,00	360,00
26	14,00	10,00	61	1244,00	888,00
27	327,00	262,00	62	32,00	23,00
28	26,00	18,60	64	227,00	162,00
29	26,00	18,60	65	295,00	210,00
33	14,00	10,00	66	18,00	13,00
34	19,50	14,00	67	18,00	13,00
35	30,00	20,00	68	28,00	20,00
36	26,00	18,55	69	140,00	100,00

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

TABLE AII (Continued)

Branch Number	Sending end bus	Receiving end bus	R (Ω)	X (Ω)
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