QUID 2017, pp. 2233-2247, Special Issue N°1- ISSN: 1692-343X, Medellín-Colombia

OPTIMAL LOCATION ALLOCATION AND MEASUREMENT OF DISTRIBUTED GENERATION WITH OPTIMAL LOCATION OF SWITCH VIA INTELLIGENT EVOLUTIONARY ALGORITHM

(Recibido el 13-07-2017. Aprobado el 26-09-2017)

Hamid Zandi
Department of Electrical Engineering, Naein Branch, Islamic Azad University, Naein, Iran

Mehdi Mahdavian
Department of Electrical Engineering, Naein Branch, Islamic Azad University, Naein, Iran

Farhad Samaie
Department of Electrical Engineering, Naein Branch, Islamic Azad University, Naein, Iran

Abstract. This paper has tried to study two special areas quite separate from distribution network studies, by presenting a novel approach in discussing the placement of automatic switches, a more favorable and more precise technical and economic justification of automation plan for distribution networks. In the meantime, first of all, by expressing the importance of the subject of research from two scientific and applied perspectives, a comprehensive comparison is mentioned in the prior approaches of switch placement. Then, by presenting the formulation for the multifunctional placement of automatic switches along with an optimal design for synchronization of automatic switches, an innovative way is proposed to solve such a problem. Finally, based on the results of the implementation on the test network developed in this study, a favorable economic justification based on the proposed approach in this paper will be presented for automation.

Keywords: Optimal location allocation, Distributed Generation, optimal location of switch, Intelligent evolutionary algorithm

Citar, estilo APA: Zandi, H., Mahdavian, M., & Samaie, F. (2017). Optimal location allocation and measurement of distributed generation with optimal location of switch via intelligent evolutionary algorithm. *Revista QUID (Special Issue)*, 2233-2247.

1. INTRODUCTION

Scientific studies of electrical energy distribution networks have always been a major contributor to power system studies with practical and applied approaches to improve the design status and operation of this sector of the power industry.

One of the methods to improve the status of these networks is to create automation with goals such as increasing reliability and reducing annual energy losses. However, due to the high cost of automatic switching devices, the economic justification for the automation plan must first be strengthened by its aspects of practicality. Therefore, the comprehensive review of the technical and economic benefits of automatic switching placement in the form of an optimization problem with the context of the multifunctional placement of controllable switching devices in the distribution network can provide a technically and economically substantiated justification for this project. Achieving an optimal economic response to the distribution network for the installation of DG's (Distributed Generation) and sectionners, considering that DG's are still distributed in the country's distribution networks manually, taking into account the beneficiary advises and not scientifically and with optimization results, The need to provide an economic solution that takes advantage of the user's perspective in terms of improving system reliability, is necessary that has been discussed in this article and the results of the proposed method confirm the validity of the proposed method.

2. Statement of the problem

A distributed network is considered which is characterized by the location of distribution, over-distribution, feeder paths, and the location and size of distributed generation sources. The objective is to determine the optimal location of storages and sectionners so that the issue is economically feasible and have the least amount of blackout in the whole network with the guarantee of the reliability of all consumers due to occurring errors. The hypotheses of the problem are considered as follows:

1. The network information including the structure of the feeders and the length of the various parts is known.

2. Load information is known at each distribution station.

3. Reliability parameters such as error rate for different feeder parts, average repair time of each part and average switching time are known.

4. Candidate locations are known for the construction of switches, including sectionners and dispersed generation.

5. The cost of energy is clear.

6. The price of the sectionners, the dispersed generation, and the cost of their installation are known.

7. The switching systems can be automatic or manual.

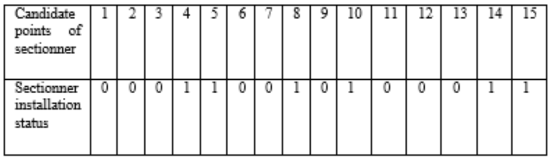
8. Managing operation of dispersed generation is at the disposal of distribution company and all of these resources are considered to be fully "dispatchable".

9. The radial network is considered.

2.1. First study case: the simultaneous placement of distributed generation and the switch in the 25 bus distribution network

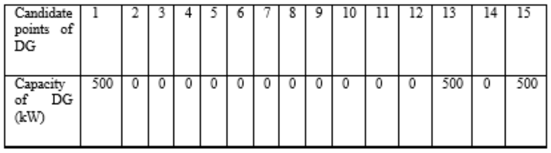
In this test, all the input information is the same as the initial information. Tables (1) to (2) show the location of the sectionners, the location and capacity of the mounted DG, and the installation costs and the profit generated by the reliability enhancement.

Table 1. The location of the sectionner on the first study



Candidate points of sectionner	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sectionner installation status	0	0	0	1	1	0	0	1	0	1	0	0	0	1	1

Table 2. The location and capacity allocated to dispersed production sources in the first study



Candidate points of DG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capacity of DG (kW)	500	0	0	0	0	0	0	0	0	0	0	0	500	0	500

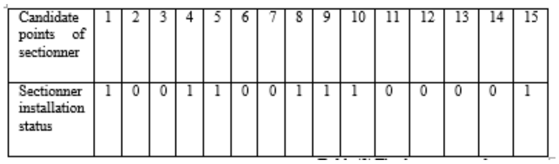
Table 3.Costs of improving reliability

cost	Amount($)
The cost of buying and installing Sectionner	2400
The cost of buying and installing DG	63000
Profit resulting from a reliable improvement	401330
Net Income Distribution Company	225930

2.2. Second study case: The effect of shortening the duration of switching and launching distributed generation

It is assumed that in the event of an increase in the level of technology in the design of sectioners as well as disturbed generation sources, the time required for switching operations is reduced. The following tables show the effect of getting half the switching times and placing the distributed generation sources in orbit to the cost of reliability and profit of distribution companies.

Table 4. The location of the sectionner on the second study



Candidate points of sectionner	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sectionner installation status	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1

Table(6)Costs of improving reliability

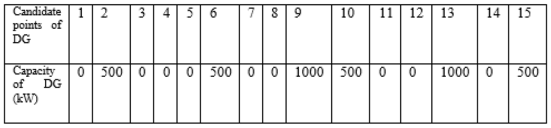
cost	Amount($)
The cost of buying and installing Sectionner	2800
The cost of buying and installing DG	42000
Profit resulting from a reliable improvement	401800
Net Income Distribution Company	357000

2.3. Third study case: The effect of reducing the number of faults

In this test, it is assumed that with the implementation of measures in the planning and operation of the network studied, the frequency of errors in all sections is halved.

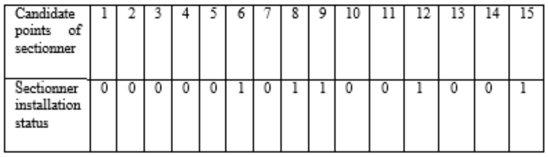
Regarding the information on the rate of error count in Table 7, in simulation for this scenario, all values are multiplied in the number of 0.5. The tables below show the effect of getting half the number of errors is reduced to the cost of reliability and profit of distribution companies

Table 5. The location and capacity allocated to dispersed production sources in the second study



Candidate points of DG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capacity of DG (kW)	0	500	0	0	0	500	0	0	1000	500	0	0	1000	0	500

Table(7)The location of the sectionner on the third study



Candidate points of sectionner	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sectionner installation status	0	0	0	0	0	1	0	1	1	0	0	1	0	0	1

Table 8.The location and capacity allocated to dispersed production sources in the third study

Table(9)Costs of improving reliability

cost	Amount($)
The cost of buying and installing Sectionner	1600
The cost of buying and installing DG	168000
Profit resulting from a reliable improvement	392180
Net Income Distribution Company	222580

2.4. Fourth study case: the effect of reducing the cost of purchasing and installing distributed generation

It is assumed in this experiment that the cost of installing DGs in the network is half the initial cost per kilowatt. In the tables below, the cost of alving the cost of distributed generation is brought to the cost of reliability and profit of distribution companies.

Table(10)The location of the secessioner on the third study

Candidate points of sectionner	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sectionner installation status	0	1	0	0	1	1	0	1	0	1	0	0	0	0	1

Table(11)The location and capacity allocated to dispersed production sources in the third study

Candidate points of DG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capacity of DG (kW)	1	0	0	1	1	0	0	1	1	1	1	1	0	1	0

Table 12. Costs of improving reliability

cost	Amount($)
The cost of buying and installing Sectionner	2800
The cost of buying and installing DG	105000
Profit resulting from a reliable improvement	481320
Net Income Distribution Company	373520

5.2. Distributed generation placement and switches and optimal configuration of the 33 bus network

In this section, the sample standard radial distribution network of 33 bus has been studied. The optimal network arrangement in the presence of distributed generation is obtained by MATLAB software using the algorithm of firefly optimization. The distributed generation studied in this paper can produce both active and reactive power.

The radial network includes a main feeder and three side feeders. The system has 33 bus and 32 parts. System switches include 32 sectionners and 5 Tie switches. Sectionner switches (separation) of the system are open in the normal state.

Deviation of power loss before the new configuration of the network and after the installation of distributed generations and after the new configuration of the network has been studied.

From the results obtained, it can be seen that the power loss range depends on the length of the line between the bus and the size of each bass. The longer the line is, the more power losses.

The results prove that new configurations (simultaneous placement) have a significant effect on reducing power losses in the distribution network.

Reducing losses will typically improve the efficiency of the distribution system. Table (13) also shows that the output of the 33 bus distribution network in the base conditions is 95.19%, which is increased by 96.41% after installing distributed generations. After the new configuration of the network output returns to 98%.

Table 13. *Stimulation results on the distribution network of 33 buses studied*

Terms of network operation	Technical parameter examined					
	Active losses	Reduction percent of active losses(%)	Efficiency (%)	Minimum voltage (p.u)	Tie keys that should be closed	Sectionner keys that should be opened
Base mode	203/46	-	95/19	0/91	-	-
With the presence of scattered production- Before the keys are present	113/45	35/98	96	0/93	-	-
With the simultaneous presence of scattered production and key	74/56	64/23	98	0/96	33 31 36 37	7 10 28 31

The optimization results in Fig. 2 show that a significant improvement in the voltage profile can be achieved with simultaneous optimization.

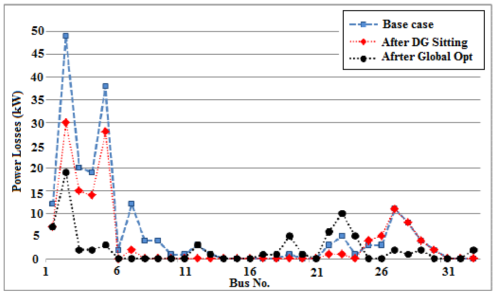


Fig 1: changes of 33-bus network power losses in different scenarios

After optimizing and configuring the new network, the maximum voltage range in the bus is 1 against 1 per-unit, and the lowest voltage range is set to 0.96 per-unit and 32 bass. This voltage range is better than the previous one. The results of efficiency and performance are shown in the proposed method.

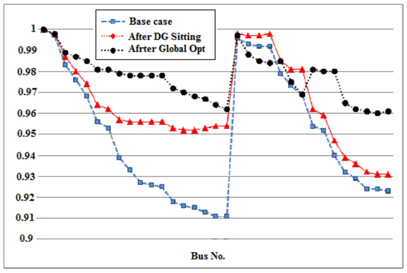


Fig 2: 33-bus network voltage profile changes in different scenarios

Figure 3 shows the convergence curve of the optimization problem for system losses, which is presented in for verifying the validity of the algorithm presented in this paper in one of scenarios.

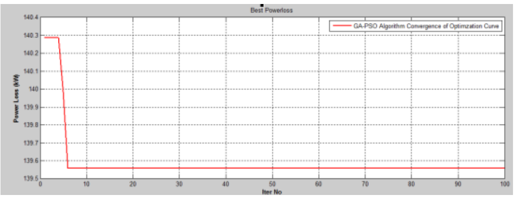


Fig 3: convergence of optimization output diagram with firefly method

3. IMPLEMENTATION IN THE NETWORK STUDIES PHASES

Designing a distribution network as one of the network's study phases requires the proper study of the study area to design the network and have sufficient vision of the future of the place of interest; therefore, studies that start at the design phase of the network can be a little more complicated than Studies have found that they are exploiting the network in operation state.

What is emphasized is that in design process , weak points can be made up better than the process that network studied in operation state.

3.1. Results of the search for optimal answer in network space losses

In this section, first, by deleting the initial arrangement of network constraints from the study process in the design phase, from the first space of the optimal answer, we investigate the sieve state of network to find an arrangement of the usually open automatic switches, whose performance annually has the minimum Power losses in network lines. Then the results will be compared with the terms of the network exploitation under technical and economic comparison. This search will be done by considering the feeder load continuity curve steps and its induction on the network load points and also considering the coincidence coefficients of the low-voltage network loads that branch out from the point of intermediate network load points. In this study, at the beginning of each main feeder, a branch of the substation of 63/20 kW, is a switch of the circuit breaker 2, and Table (14) indicates their position in the test network.

Table (15) also shows the automatic usually automatic switches that is chosen in the primary layout of the network under operation, and the automatic switches that are usually open in the optimal arrangement of the network losses after design.

Table 14. Condition of circuit breaker keys

To branch	From base	Circuit breaker key characteristic
s-1	B-0	CB1
s-17	B-17	CB2
s-36	B-17	CB3

Table 15. The location of the test points network chain

Optimal grid layout after design		Initial grid of the network under exploitation	
On the branch	Automatic key characteristic	On the branch	Automatic key characteristic
S-10	RC-1-S-10	S-10	RCS -1-S-35
S-12	RCS-2-S-12	S-10	RCS-2-S-34
S-7	RCS-3-S-7	S-10	RCS-3-S-33
S-8	RCS-4-S-8	S-10	RCS-4-S-36
S-28	RCS-5-S-28	S-10	RCS-5-S-37
S-27	RCS-6S-37	S-10	RCS-6-S-7

3.2. A survey of network losses indicators

To analyze the implementation studies on the test network in the first search space, the amount of active power losses and reactive power losses are measured first.

The amount of active power losses and reactive power losses as the most basic indicators of network losses, for all steps of the feeder load continuity curve according to Fig. 4 for the sieve arrangement and according to Fig. 5, for arrangement of the minimum optimal , resulting of that after design, Are expressed. Also, the amount of active power losses and reactive power losses for the primary arrangement under network operation are also shown in Fig. 6.

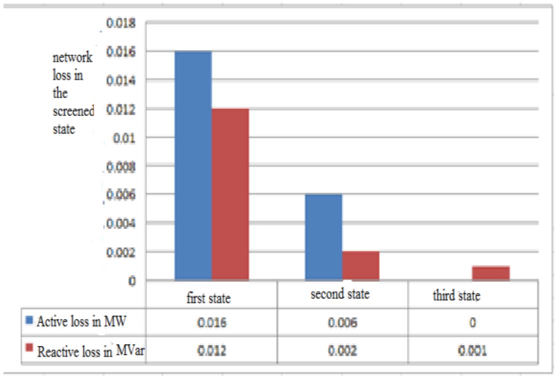


Fig (4): Network loss in the screened state

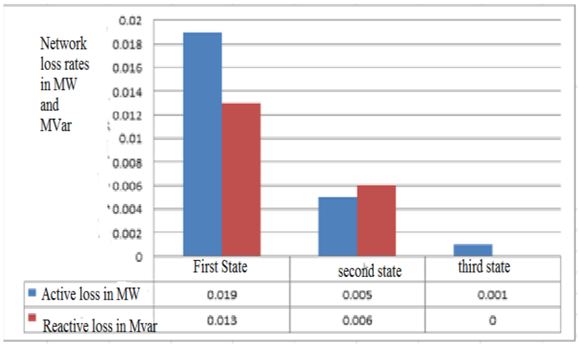


Fig (5): Network loss in the optimized radial configuration and minimum losses

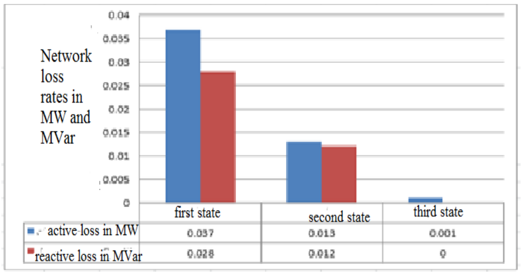


Fig 6: network losses in the operation radial configuration

In figure (4), study test network is in the screened state with minimum losses and in order to change its arrangements to the radial form as a normal configuration of the distribution network, increasing the network losses is necessary due to the increasing current passing from the feeders. This event happens in the network because the popular equation $r.(i_1 + i_2)^2 > r.(i_1^2 + i_2^2)$ holds permanently. In this equation, r is one line resistance and i_1 and i_2 are currents passing from two parallel lines with equal resistance. Therefore, in the proposed algorithm, it is tried to minimize the losses in final radial losses.

The amount of radial configuration losses under operation is presented in figure (6). Comparison of figures (5) and (6) shows that active power and reactive power losses in the optimal configuration resulted from design phase is lower than active and reactive power losses in the initial configuration under operation of studies test network.

In the same way, annual energy loss in the radial configuration obtained by optimal design in figure (7) as well as annual energy loss in the initial radial configuration under operation is shown in the figure (8). It is worthy to mention that time coefficients of separated load continuity curves were used in order to change the lost power to annual lost energy. Comparison of figures (7) and (8) will observe significant reduction in the annual energy loss in the optimal configuration resulted from system design phase and therefore, the optimal network arrangement, in addition to minimum power losses, has minimum energy loss.

Electric energy losses in the distribution networks cause that distribution companies always suffer from the cost of energy losses. In fact, in this case, distribution network device act as a large consumer which consumes a large part of input power in the network continuously and therefore, significant reduction of cost of these losses has been always considered by the distribution network beneficiaries. The cost of network energy loss in the optimal radial configuration obtained from design phase as well as initial configuration of the network is shown according to figure (9) as the plan financial indicators in the search space. Figure (9) which is the numerical comparison of the technical and economic superiority of the optimal plan obtained by imposing the proposed algorithm in the first search space indicates that about 52012.5$ will annually reduce from the cost imposed to the distribution networks due to cost of losses. Therefore, optimal configuration obtained from design phase is the configuration with minimum power losses, and by imposing time coefficients of load continuance curve, it is an configuration with minimum annual energy loss. This network configuration should be established as the permanent configuration of the system in the normal performance moments and therefore, optimized open automatic switches should always place on the open feeders in this arrangement.

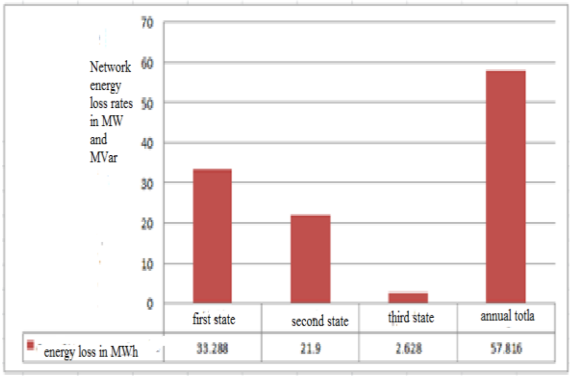


Fig (7): annual energy loss in the optimal radial configuration by minimum losses and time coefficients of load continuance curve

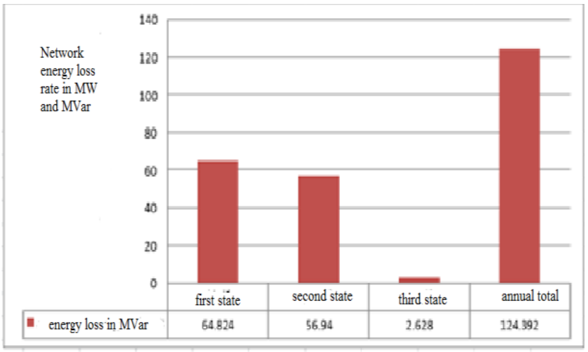


Fig (8): annual energy losses in the optimal radial configuration by observing time coefficients of load continuance curve

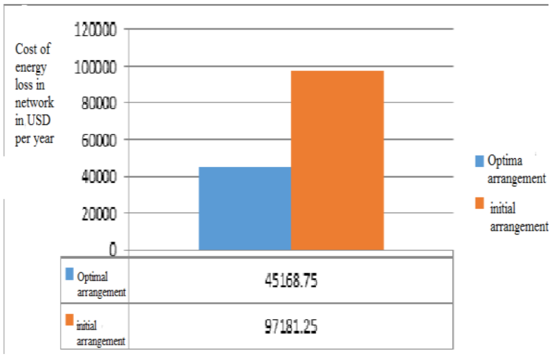


Fig (9): cost of network loss in the optimal radial configuration after initial design and configuration

3.3. Resulting of searching optimal solution in the network reliability space

In the second space for searching optimal solution, by assuming the fixed place for some specified automatic switches in the previous step as opens switches, step by step search of automatic switches was done which has the most optimal effect in reducing the unmet annual energy of subscribers. This selection will correspond with a state in which the annual interruption time of network for clients becomes minimal.

Placed automatic switches in this section are those switches which will be closed in the normal condition and during the fault, they will isolate the defected part of the network and prepare the network for primary maneuver and in maneuver with multiple switching will open loops caused by connecting multiple maneuver switches. Table (16) indicates optimal automatic switches in the closed state in two study phases of the network. In this table, selected automatic switches were coded following the switches selected in the previous research space and therefore, displaying RCS-7-S-19-U code indicates the seventh automatic switch which has been installed on the upstream place on the feeder 19. The position of this switch is from buss B-18 to feeder S-19. In the same way, these switches were coded based on their priority up to 16th switch.

Table 16. Final position of closed automatic switches in the distribution network study phases

Initial configuration of operational network			**Optimal configuration of network after design**		
Automatic switch characteristics	From bus	To feeder	Automatic switch characteristics	From bus	**To feeder**
RCS -7-S-18-U	B-18	S-18	RCS -7-S-19-U	B-18	**S-19**
RCS -8-S-4-U	B-4	S-4	RCS -8-S-3-U	B-2	**S-3**
RCS -9-S-22-U	B-22	S-22	RCS -9-S-22-U	B-2	**S-22**
RCS -10-S-12-D	B-12	S-12	RCS -10-S-21-U	B-20	**S-21**
RCS -11-S-27-U	B-26	S-27	RCS -11-S-33-U	B-20	**S-33**
RCS -12-S-24-U	B-23	S-24	RCS -12-S-34-U	B-14	**S-34**
RCS -13-S-19-U	B-18	S-19	RCS -13-S-24-U	B-23	**S-24**
RCS -14-S-30-U	B-29	S-30	RCS -14-S-5-U	B-4	**S-5**
RCS -15-S-9-D	B-9	S-9	RCS -15-S-18-U	B-1	**S-18**
RCS -16-S-6-U	B-5	S-6	RCS -16-S-30-U	B-30	**S-30**

3.4. Network reliability indices

For analyzing implementation studies on the network, various charts and tables will be studied in various forms that each of them indicates the technical and economic indicators of the system in distribution network reliability phase. For comparison of two phases of design and operation which have two different configuration of the network, first we study the sum of annual unmet energy by observing the time coefficients of load continuance curve in the automatic switch placement steps. Figures (10) and (11) indicate the value of this indicator in the design phase and operation phase studies, respectively.

In order to simplify the implementation results, we will separate automatic switches in general studies. In this case, 6 first switches allocate to the first search space and the remained switches which are determined in second search space, will be known as first to tenth switches in the reliability studies' space.

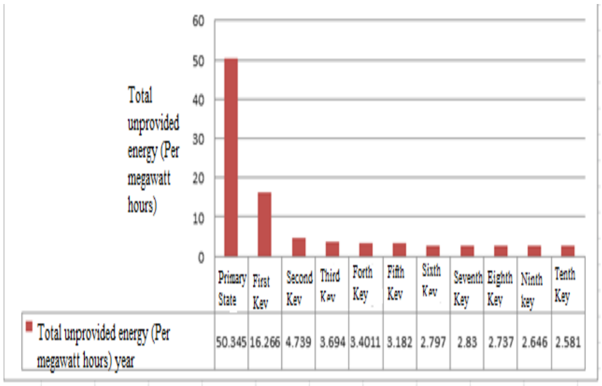


Fig 10: total unmet annual energy by observing time coefficient of load continuance curve in placing switch in design phase

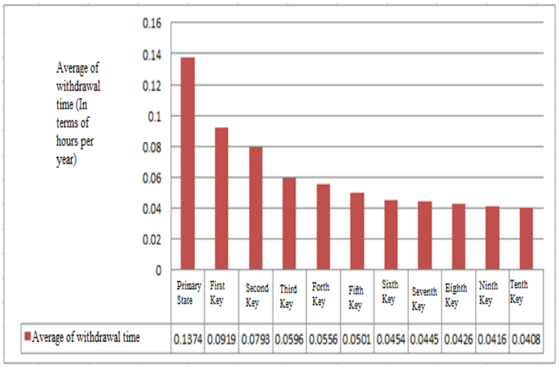
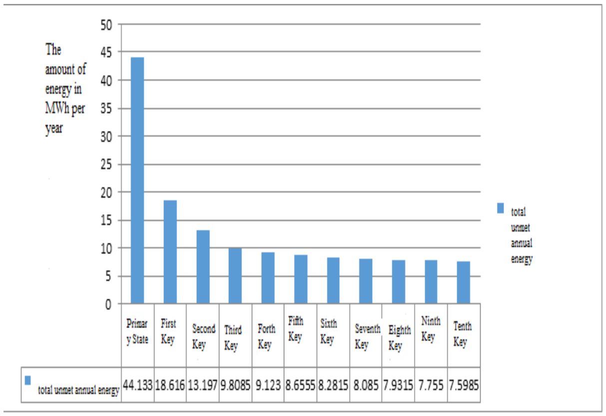


Fig 11: total unmet annual energy by observing time coefficient of load continuance curve in switch placement in network operation phase



Because of the homogeneity of the importance of system average interruption duration index, the clients with the unmet energy indicator in the automatic switch placement in the second search space, we will study this indicator for design and operation phases of the network studies which have developed two different final arrangements from the same network in the figures (12) and (13), respectively.

Comparison of figures (10) to (13) which carry the major indicators of network reliability, we found that regarding the public operation of the distribution networks in higher reliability indicators in which losses' study has lower importance, the condition of the network under operation was better in terms of reliability indices than optimal configuration obtained by design phase. But the condition of these indicators in all proposed algorithm steps will be significantly better in the network obtained from design phase than the network which was based on the higher reliability indices. The annual cost of unmet energy which is considerable in the large networks will be different based on the network configuration and the perspective of operator for financial evaluation of reliability. This cost is defined in the system-oriented view as the lost profit due to not selling energy to the clients in the service network; although in the customer-oriented view, this cost is described as the compensation which will be paid to the subscribers due to not supplying the feed.

4. THE STUDY OF ALGORITHM STOP CRITERIA AND DETERMINING THE OPTIMAL SOLUTION

The statistical study of above implementation results in the network reliability space indicates the sensible superiority of reliability indicators during all automatic switch placement steps in the minimum network losses configuration relative to the other configurations. But what is the optimal solution of the problem? In other words, in which step of studies, the switch placement according to the proposed algorithms should be stopped?

In answering this question, we should say that regarding the proposed optimization method in this article, we cannot use stop criteria of the current methods because we are always observing unmet energy reduction and improvement of the reliability indicators in the consecutive steps of the proposed algorithm.

Therefore, all reasonable indicators are places in the studied algorithm in order to determine the stop condition of the implementation of proposed algorithm clearly. Given indicators include 6 major parts which will be expressed in two system studies phases and two financial evaluation views of reliability in the switch placement steps.

1-total annual cost of the system in reliability studies;

2-total annual profit of the system in reliability studies;

3-percent of unmet energy reduction of system relative to initial state of the network;

4-percent of reducing average annual interruption time of subscribers relative to the network initial state;

5-percent of system unmet energy of the system relative to the previous state of switch arrangements;

6-percent of reducing average annual interruption time of system subscribers relative to the previous switch arrangement;

Stop first index: total annual cost in the reliability studies is equal with total cost of unmet network energy and investment cost, annual cost of repairing and maintaining the network automatic switches in the reliability phase. The value of this indicator in the switch placement steps during reliability studies in customer-oriented view, will be higher than its corresponding value in the system-oriented view due to significant increase in the unmet energy cost. However, this cost will be different in the network study phases and its reason is non-homogeneity of unmet energy cost in the final configuration of the study phases. In this indicator, annual cost of network minimum losses configuration resulted from the design phase in each financial evaluation of reliability is always lower than corresponding values in the other arrangements of the network like operation arrangement.

In fact, in the general view of studies, the cost of selected automatic switches in the first search space will influence similarly on the all indices and for this reason, the elimination of open switches will not disturb the comparison of indicators. In the initial state of starting second space studies, total value will only include cost of the unmet energy.

Total annual cost minimized in the second step in the system-oriented view during study in the network design phase and therefore, in this study, based on the given indicator, selecting 2 first switches will be an optimal selection. If customer-oriented view is considered in the study phase, the selection of first four switches will be optimal. If the study phase is based on the initial network configuration and operation conditions, in the system-oriented view, selecting 3 first switches and in the customer-oriented view, selecting 6 first switches will be an optimal solution.

Since this criterion indicates different behavior in the system study phase and during reliability evaluation views, it cannot be considered as suitable algorithm stop criterion.

Second stop index: annual profit in the reliability studies is income of reducing unmet energy in the network minus total annual cost which has been studied in the first indicator. Annual profit will be higher in the switch placement steps during reliability studies in the customer-oriented view than system-oriented view due to the significant increase in the unmet energy cost. However, this cost will be different in the network study phases in each view of financial evaluation of reliability and its reason is non-homogeneity of the unmet energy in the final configuration obtained by the study phases. In this indicator, annual profit of minimum network losses caused by design phase in all financial evaluations of reliability, is higher than corresponding values in the other arrangements in the operation network.

Annual profit during study in the network design phase in the system-oriented view maximizes in the third step and therefore, in this study, based on the given indicator, selection of 3 first switches is an optimal selection. This is while in this study phase, if the customer-oriented view is considered, even the selection of more than 10 switches will encompass increase in the profit. If the study phase was based on the initial configuration of the network and operation condition, in the system-oriented view, selecting 3 first switches and in the customer-oriented view, selecting more than 10 switches will increase the profit. Since this criterion shows similar behavior in each system study phase in both reliability evaluation views, it can be one of the suitable criteria for stopping the algorithm.

Stop third index: the percent of unmet energy reduction relative to the initial network configuration (only open automatic switches are in the network) in the consecutive steps of switch placement is always higher in the minimum network losses in each step of the proposed algorithm than the corresponding values in other configurations of the operational network.

In order to study this indicator for stopping the algorithm steps, we can say that the percent of reducing network unmet energy relative to initial state will always increases by increasing automatic switches and therefore, this indicator is not suitable stop criteria.

Stop fourth index: the percentage of average annual interruption of the clients relative to the initial state of network configuration (only open automatic switches are in the network) in the consecutive steps of switch placement is higher than minimum network losses in other network arrangements.

In examining this index for stopping the algorithm steps, we can say that average annual interruption index relative to the initial state will increase by increasing automatic switches. Therefore, this index is not a suitable index as a stop criterion.

Stop fifth index: the percent of reducing unmet energy relative to the previous state of network switch configuration in the switch placement steps is always higher in minimum network loss configuration in each step of the proposed algorithm.

An interesting point is that in this index, despite system study phase, always 3 first switches will be optimized due to the highest reduction of unmet energy relative to the previous states. Remembering the obtained result of annual profit index as the second stop phase will be useful in proving this statement. These switches are basically selected due to the topology of the network and are not related to the financial evaluation of reliability with its abundant uncertainties and therefore, this criterion can be a suitable criteria for stopping the proposed algorithm. It is necessary to mention that this criterion has been introduced in the proposed algorithm as OFR. In this section, if the percent of reduction for stopping algorithm was %10, this algorithm will be stopped after third switch.

Stop sixth index: the percent of average annual interruption index in the general descriptive state is similar to the description of the fifth stop index. The value of this index is always higher that network minimum losses in each step of the proposed algorithm relative to the other configurations of the network. It is interesting that in this index, like the fifth index, despite study phases, always 3 first phases will be optimal switches due to the highest values for this index and therefore, this index, like the fifth index and OFR parameter, it can be considered as a suitable index for stopping the proposed algorithm.

5. SUMMARY OF IMPLEMENTATION RESULTS

Regarding that implementation results in the proposed algorithm were studied in solving controllable switches placement problem during double spaces in the above-mentioned paragraphs, for expressing the summary of the results, the annual energy losses in the study phase of the distribution network will be presented for initial configuration and minimum loss configuration according to the figure (14).

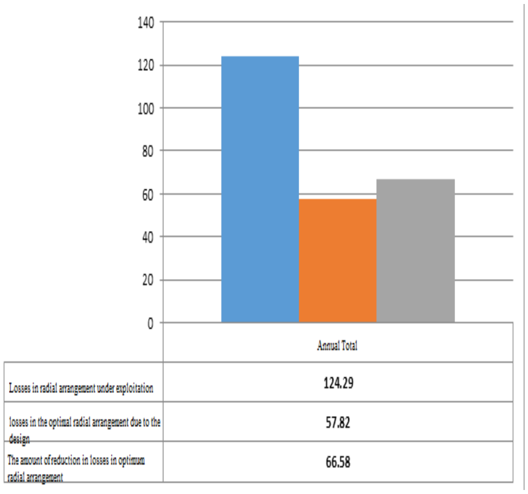


Fig 14: comparing annual energy losses in two operation and optimal states

5.1 Technical and economic justification of the proposed approach

In this section, by combining the major criteria obtained by implementation of the proposed algorithm, we present the final conclusion of this article in technical and economic justification in the optimal plan. One of these indices is total unmet energy and annual lost energy in the network automatic switch placement which has been compared in the distribution system study phases.

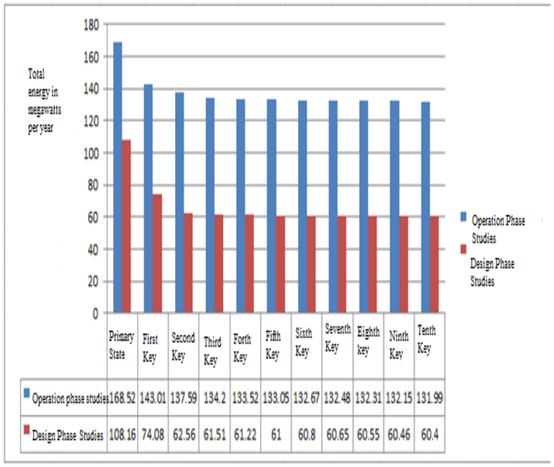


Fig 15: total unmet energy and annual lost energy by observing load continuance curve-comparing operation and design phases

This index is shown in the figure (15) and indicates the minimum total energy in all study steps of the proposed algorithm relative to the general process of switch placement problem.

Minimum value of this total energy, due to the reduction of lost energy in one hand, and reduction of unmet energy, on the other hand, is for all implementation states based on the proposed algorithm. This energy reduction, in the general state, will indicate another index which is defined as the returned energy. This energy enters into the supply cycle of the subscribers and according to the figure (16), it is emphasized that the return of energy obtained by the proposed algorithm in the automatic switch placement discussion is higher than returned energy caused by imposing the general algorithms of automatic switch placement on the test network.

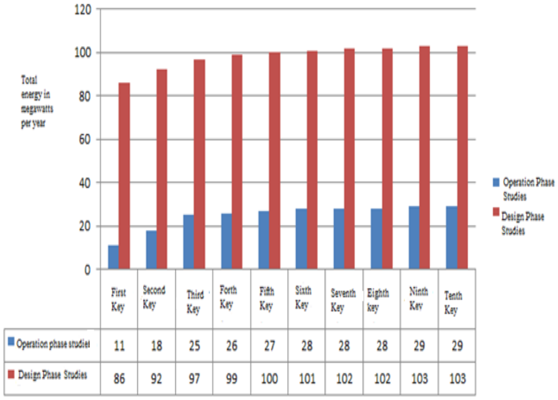


Fig 16: total annual returned energy to the feed cycle by observing the time coefficients of load continuance curve-comparing operation and design phase

Finally, for ending the comparison of the study criteria, the most famous criterion of engineering studies which is the total profit, will be studied in system-oriented and customer-oriented views according to the figures (17) and (18). What is inferred from these two figures is that by considering the fixed investment in the distribution network, we will reach higher economic profit relative to the general process of the switch placement problem. Due to the establishment of the open automatic switches in the deep points will state better voltage profile and load balance of network feeders relative to common switch placement views, in addition to economic superiority of the process.

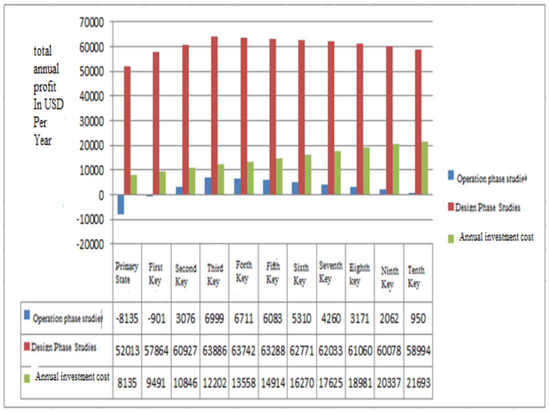


Fig (17): total annual profit obtained by reducing losses and unmet energy by considering annual investment cost of switches-comparing design and operation in general state of system-oriented view

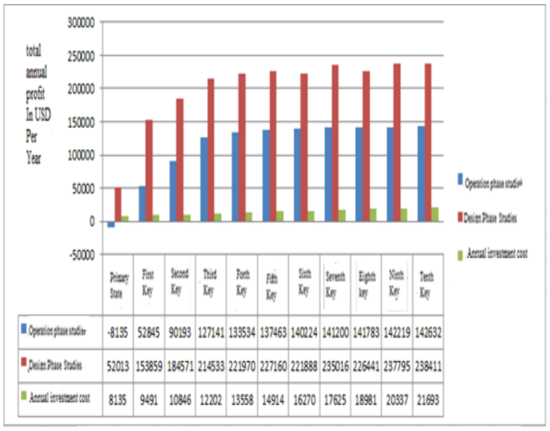


Fig (18): total annual profit obtained by reducing losses and unmet energy by considering annual investment cost of switches-comparing design and operation phases in customer-oriented view

6. CONCLUSION

- By studying placement of the dispersed generations and switches and optimal configuration of 33-bus network, regarding the output of optimization results, the optimal place of dispersed generation is on the buses number 12, 17, 22, 25 and 27. By solving the optimization problem, it is concluded that 4 tie switches should be closed which are switches 33, 35, 36 and 37 and section switches which should be open is switches number 7, 10, 28 and 31.

- From obtained results, we can observe that the ranges of power loss depends on the length of line between buses and size of each bus. The longer the line, the higher the losses. Similarly, regarding the results, we can see that the larger the load, the higher will be the power losses. We can observe that the dispersed production influences the reduction of system power losses, especially on the buses near to the dispersed generation.

- Before new configuration of 33-bus network, total active losses are 203.46Kwatt. Total active losses after installing 5 dispersed generation units was 133.45kwatt while total active losses after new configuration in the presence of dispersed generation is 74.65kwatt.

- The percent of power losses reduction after installing dispersed generations is %35.68, while the percent of loss reduction after new installation and configuration (total simultaneous optimization and dispersed generation) is %64.23. the results proved that the new configuration has significant effect in the reduction of power losses in the distribution network. Loss reduction will improve the efficiency of distribution system.

- We can observe that integrating dispersed generations on the buses has considerable effect on the improvement of the voltage profile, especially on the buses which are closer to the dispersed generation. Voltage improvement is done on all busses because voltage range has reached its maximum range. The results of optimization show that we can achieve significant voltage profile improvement by simultaneous optimization.

- Although the annual unmet energy in the reliability study in optimal configuration was higher in design phase than operation phase, from automatic switch placement in the network onward, the value of this index in minimum loss configuration in all steps is lower than its corresponding values in other network configurations.

- Average annual interruption duration in automatic switch placement in minimum network loss configuration is lower than corresponding configurations of the network in operation state.

- Increasing the number of switches in the distribution network will reduce the annual unmet energy index and higher reduction of annual interruption duration index of network clients.

- The reduction of annual unmet energy and also reduction of average annual interruption duration has the higher value in network minimum loss configuration than other configurations.

- The results obtained by comparing these indices in the consecutive steps of automatic switch placement in all states in the study phases, under the views about financial evaluation of reliability, indicates that customer-oriented view always have higher profit due to the significant increase of the unmet energy and it has better economic justification.

- Also, the customer-oriented view has higher value in the system-oriented view due to the significant increase of unmet energy cost. The higher cost indicated the higher value of the unmet energy in the customer-oriented view. However, the profit and cost in each view of the study phases is different from other phase and its reason is non-homogeneity of unmet energy in the final conclusion of study phases.

- Total annual cost and annual profit in the network minimum losses configuration obtained by design phase in each view of financial evaluation of reliability, has better condition relative to the corresponding values of other network configurations in operation state.

REFERENCES

A. Jamal, S. Suripto & R. Syahputra (2015). Multi-Band Power System Stabilizer Model for Power Flow Optimization in Order to Improve Power System Stability, Journal of Theoretical and Applied Information Technology (JATIT), 80(1), 116-123.

A. Tjahjono, A. Priyadi, M.H. Purnomo, M. Pujiantara (2014). “Overcurrent Relay Curve Modeling Using Adaptive Neuro Fuzzy Inference System”, IEEE Makassar International Conference on Electrical Engineering and Informatics.

A. Tjahjono, D.O. Anggriawan, A. Priyadi, M.H. Purnomo, M. Pujiantara (2015). “Overcurrent Relay Curve Modeling and Its Application in the Industrial Power Systems Using Adaptive Neuro Fuzzy Inference System”, IEEE International Conference on Computational Intelligence and Virtual Environments for Measurement Systems and Applications.

A.Merlin, H.Back, (1975). “Search For A Minimum Loss Optimal Spanning Tree Configuration For An Urban Power Distribution System”. Proceedings Of 5th over

System Computation Conference, Cambridge U.K, Pp 12-16.

A.Moradi, M.F.Firuzabadi,"Optimal Switch Placement In Dist. Systems

A.Moradi, M.Fotouhi.Firuzabadi and et al., (2005). "A Reliability Cost/Worth Approach to Determine Optimum Switching Placement in Distribution Systems", IEEE/PES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian, China.

A.R Abdelaziz, A. Habachi, (2002) "Hierarchical Genetic Algorithm-Based Switching Device Placement In Distribution Systems", 11th Mediterranean IEEE, Electrotechanical Conference, MELECON, Cairo, Egypt, Pp. 585-589. May..

E.D.Tuglie & et al., (2004)." An Optimal Strategy for Switching Devices Allocation in Radial Distribution Network",IEEE AFRlCON, Pp.683-690

G.Ceil and F.Pilo, (1999). "Optimal Sectionalizing Switches Allocation In Distribution Networks", IEEE Trans. On Power Delivery, Vol. 14, No. 3, July, Pp. 1167-1172.

G.Levitin, Sh.Mazal-Tov, D.Elmakis, (1995). "Optimal Allocation Of Sectionalizers In Radial Distribution Network with Alternative Supply ", Proc. Of 1995 Stockholm Power Tech Conference, PS 25-01-0034, PP. 761-764, 5 May.

G.Levitin, Sh.Mazal-Tov, D.Elmakis (1994), "Optimum Sectionalizer AllocationIn Electric Distribution Systems By Genetic Algorithm, Electric Power System Research, No. 31, Pp. 97-102.

H.Falaghi, M.R.Haghifam (2007). "Simultaneous Allocation Of Sectionalizers and Tie Points In Electric Distribution Systems", International Journal Of Power And Energy Systems Journal. No. 203, Pp. 3611.

J.H.Teng & C.N.Lu (2002). "Feeder Switch Relocation for Customer Interruption Cost Minimization", IEEE Transactions on Power Delivery, Vol. 17, No. 1,January 2002, Pp. 254-259.

P.M.S.Carvalho, L.A.F.M.Ferreira and A.J.Cerejo Da Silva, (2005). "A Decomposition Approach to Optimal Remote Controlled Switch Allocation in Distribution Systems", IEEE Transactions on Power Delivery, Vol. 20, No. 2, April 2005, Pp. 1031-1036

P.Wang, Billinton, (1998). "Demand-Side Optimal Selection of Switching Device In Radial Distribution System Planning", IEE Proceedings, Generation Transmission Distribution, Vol. 145, No. 4, July, Pp. 409-414.

Pandi, V. R., Zeineldin, H. H., Xiao, W. (2013). "Determining optimal location and size of distributed generation resources considering harmonic and protection coordination limits." IEEE Transactions on Power Systems. 28 (2). pp.1245-1254. DOI: 10.1109/tpwrs.2012.2209687.

R. Syahputra, I. Robandi & M. Ashari (2014). Distribution Network Efficiency Improvement Based on Fuzzy Multi-objective Method, IPTEK Journal of Proceedings Series. 1(1), 224-229.

R. Syahputra, I. Robandi & M. Ashari (2014). Optimal Distribution Network Reconfiguration with Penetration of Distributed Energy Resources, Proceeding of ICITACEE 2014, Semarang, Indonesia.

R. Syahputra, I. Robandi & M. Ashari (2014). Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method, International Review of Electrical Engineering (IREE), 9(3), 629-639, 2014.

R. Syahputra, I. Robandi & M. Ashari (2014) Performance Analysis of Wind Turbine as a Distributed Generation Unit in Distribution System, International Journal of Computer Science & Information Technology (IJCSIT), 6(3), 39-56.

R. Syahputra, I. Robandi & M. Ashari (2015). Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm, International Review of Electrical Engineering (IREE), 10(2), 293-304.

R. Syahputra, I. Robandi & M. Ashari (2015). Reconfiguration of Distribution Network with DER Integration Using PSO Algorithm, TELKOMNIKA, 13(3), 759-766, 2015.

R.Billinton and S.Jonnavithula (1996) “Optimal Switching Device Placement In Radial Distribution System”, IEEE Trans On Power Delivery, Vol. 11, No. 3, July, Pp. 1646-1651

Using Trinary Particle Swarm Optimization Algorithm”, IEEE Transactions On Power Delivery, Vol. 23, No. 1, Pp. 271-279,January 2008.

Y.Wenyu, L.Jian, Y.Jianminl and et al. (2004). Optimal Allocation of Switches in Distribution Networks”, Proceedings of the 5th World Congress on Intelligent Control and Automation, Hangzhou, P.R. China, Pp. 5155-5159, Jun 2004.