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Reliability Improvement of System Reconfiguration by Considering the Time-varying Load with Optimal Scheduling of Distributed Generations

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Abstract

The distributed generation (DG) locations have significant impacts on network configuration and loss. By fixing DGs in suitable optimal locations and by generation power based on the load conditions, the total power loss in the system can be reduced and the system reliability can be improved. Distribution system reliability assessment is able to predict the interruption profile of a distribution system based on system topology and component reliability data. In this paper, Fuzzy algorithm is used to obtain the optimum position and size of DG units in the distribution network in order to reduce network loss at the lowest cost. Also, a time-varying load curve for optimal scheduling of DGs considering active power loss and DG cost is used. The result shows the improvement of bus voltage profile and decrease losses due to install the optimal size of DGs by optimal scheduling of distributed generations. The test system is Yangon 66kv; 45-bus and the results obtained reveal the effectiveness of proposed method.

Keywords: Distributed generation; Fuzzy algorithm; Loss reduction; Optimum position; System reliability.

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1. Introduction

The accurate load representation is not easy issue regarding to its changeable nature and variety. It is hard to predict the system behavior in case of outage, voltage or frequency variation or other factors that can affect system stability without proper information, or system behavior data. The powers system are mostly nonlinear and operates in constantly changing conditions, so it is hard to obtain precise information and data about i.e. generators or loads during disturbance. Reliability is one of the most important parameter to analysis the performance of the system. Reliability can be calculated on both customer side and utility side. Reliability analysis is generally done in distribution system because most of fault occurs in distribution system only [7]. The parameters for calculation of reliability improvement are:

Momentary interruption of Single operation of an interrupting device is that results in a voltage zero. For example – two circuit breaker operations equals two momentary interruptions [2]. Sustained interruption of any interruption not classified as a momentary interruption. Interruption is longer than five minutes [2]. Distribution system reliability indices is the most common distribution indices include the System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), System Average Interruption Frequency Index (SAIFI), Momentary Average Interruption Frequency Index (MAIFI), Customer Average Interruption Frequency Index (CAIDI), Customers Interrupted per Interruption Index (CIII), and the Average Service Availability Index (ASAI) [6]. The performance of Yangon distribution system becomes inefficient due to the reduction in voltage magnitude and increase in distribution losses. With this regard, changing environment of power systems design and operation have necessitated the need to consider active distribution network by incorporating Distributed Generation units (DGs) sources [4]. DGs are grid-connected or stand-alone electric generation units located within the electric distribution system at or near the end user. The case study area is Yangon 66kv distribution system and the total customer of Yangon is 1141097 customers.

2. Research Methodology

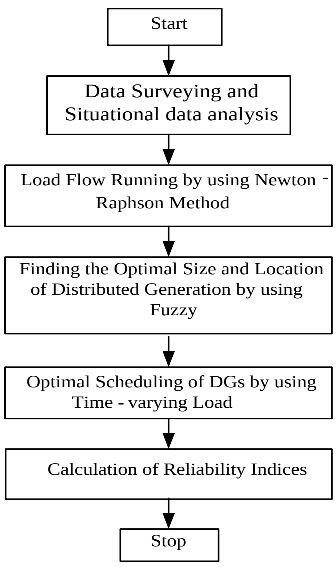

Figure 1: Flow Chart of the proposed method

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(2.1) Data surveying and situational data analysis

(2.2) Load flow running by using Newton-Raphson method

(2.3) Finding the optimal size and location of DGs

(2.4) Optimal Scheduling of DGs by using time-varying load

(2.5) Calculation of Reliability Indices

2.1 Data surveying and situational data analysis

The test system used in this paper is Yangon 66kv distribution system. In Yangon, if a transformer or line is failure, the repaired time takes long time that is about 48 hours or more. It is not reasonable for power system improvement.

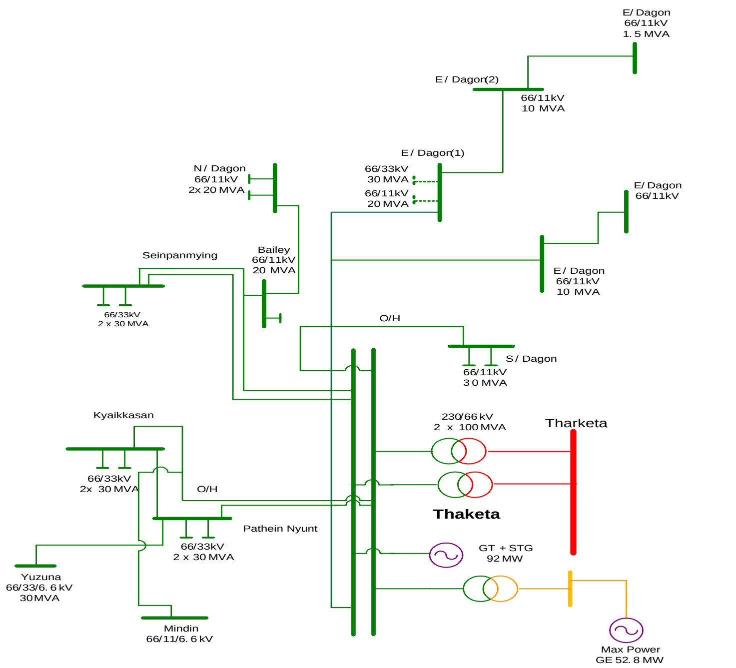

Figure 2: Test system of Yangon distribution system

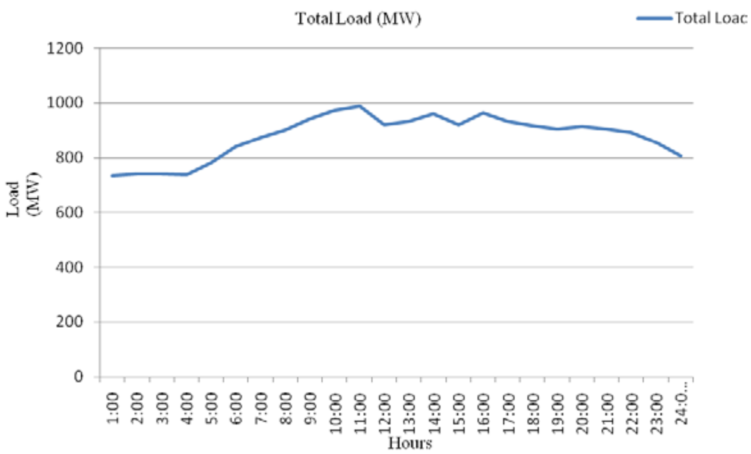

Figure 3: Daily Load of Yangon Distribution System

2.2 Load flow by Newton-Raphson method

The following table-2 shows the bus voltage (per unit) of each bus of power flow solution by Newton-Raphson Method. Some of the radial bus voltages are out of the permissible range (±5%). Table-2 indicates that the total load of 989.710MW and the total loss of 6.567MW. For the permissible range of bus voltages, Fuzzy algorithm is used for optimum position of distributed generation.

Table 1: Power Flow Solution by Newton-Raphson Method

Descriptions	MW
Total Load	989.710
Total Loss	6.567

2.3 Implementation of Fuzzy Method

Two objectives are considered while designing a fuzzy logic for identifying the optimal DG locations. The two objectives are: (i) to minimize the real power loss and (ii) to maintain the voltage within the permissible limits. Voltages and power loss indices of distribution system nodes are modelled by fuzzy membership functions. A fuzzy inference system (FIS) containing a set of rules is then used to determine the DG placement suitability of each node i^n the distribution system.

In the first step, load flow solution for the original system is required to obtain the real and reactive power losses. Again, load flow solutions are required to obtain the power loss reduction by compensating the total active load at every node of the distribution system. Loss Reduction Index (LRI) value for i^{th} node can be obtained using equation 1.

$$PLI = \frac{(Lossreduction(i) - Lossreduction(min))}{(Lossreduction(max) - Lossreduction(min))} \qquad (1)$$

Seven membership functions are selected for PLI. They are VL, L, ML, M, MH, H and VH. All the seven membership functions are triangular as shown in figure-4. Seven membership functions are selected for Voltage. They are VL, L, ML, M, MH, H and VH. These membership functions are trapezoidal as shown in figure-5. Seven membership functions are selected for DSI. They are VL, L, ML, M, MH, H and VH. These seven membership functions are Gaussian as shown in figure-6.

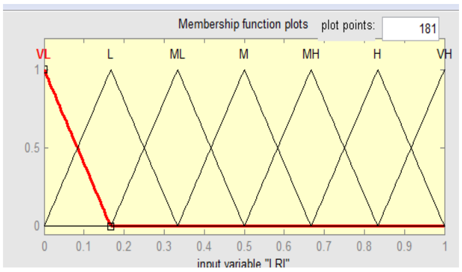

Figure 4: Specifying the first input Variables as PLI

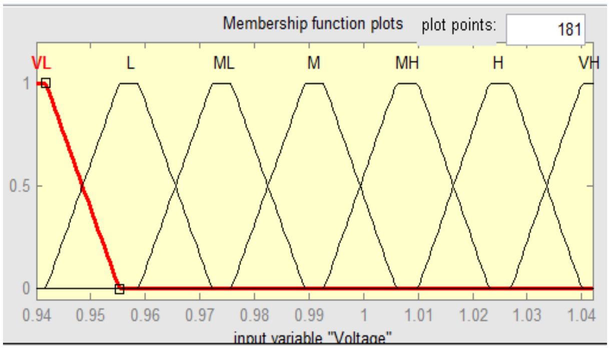

Figure 5: Specifying the second input Variables as VOLT

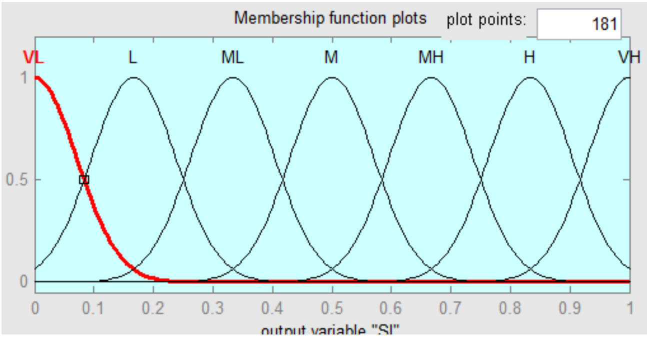

Figure 6: Specifying the Output Variable Suitability-Degree

IF premise (antecedent), THEN conclusion (consequent). For determining the suitability of DG placement at a particular node, a set of multiple-antecedent fuzzy rules has been established [5].

Table 2: Rule Base for Suitability Index

Voltage / LRI	VL	L	ML	M	MH	H	VH
VH	VH	VH	H	H	MH	MH	M
H	VH	H	H	MH	MH	M	ML
MH	H	H	MH	MH	M	ML	ML
M	H	MH	MH	M	ML	ML	L
ML	MH	MH	M	ML	ML	L	L
L	MH	M	ML	ML	L	L	VL
VL	M	ML	ML	L	L	VL	VL

Total load and line loss are calculated by using MATLAB software. Firstly, load flow is running to obtain network losses. Then power loss reduction is evaluated by compensating the same minus active load at every node, and load flow solutions are required. Power loss index (LRI) can be evaluated by eq.1 that normalizes loss reduction to take values between minimum and maximum such that the highest reduction takes the value of 2.096 and the lowest reduction takes the value of -0.708.

Table 3: Calculation Table

Bus	Ploss_orginal	Ploss_new	Ploss_reduction(PLI)	Volt_ibus	LRI	Suitability
22	6.567	5.635	0.932	0.94	0.584879	0.667
26	6.567	6.298	0.269	0.945	0.348431	0.61
31	6.567	6.139	0.428	0.946	0.405136	0.601

The suitability indices were calculated by using loss reduction index and voltage.

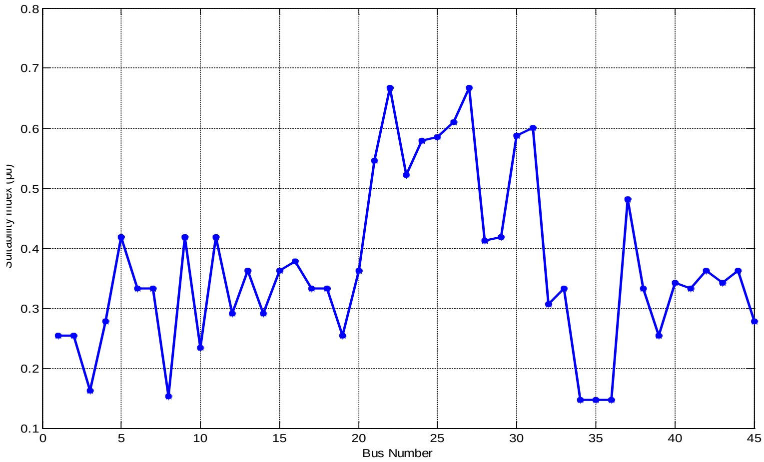

Figure 7: Suitability Index

According to the calculation results, the highest suitability indices of buses are bus number 22, 26 and 31. For the improving of bus voltage profile and decrease losses, the optimal sizes of DGs are installed in these buses.

2.4 Optimal Scheduling of DGs by using Time-varying Load

Table 4: Maximum Power Rating

Line	Size	Ampere (from table)	Power Factor	Stability Margin	Power (MW)
Bus 21-22	605MCM	760A	0.85	0.7	52.6
Bus 25-26	120mm^2	460A	0.85	0.7	31.3
Bus 30-31	397.5MCM	590A	0.85	0.7	40.8

Table 5: Comparison of the Best Case by Hourly

Hours	Case	Ploss	Q loss	Ploss_org
1:00	Case 3	5.43	27.113	5.664
2:00	Case 3	5.394	26.743	5.773
3:00	Case2	5.661	28.826	5.717
4:00	Case 3	5.27	26.941	5.912
5:00	Case 3	4.824	23.627	5.71
6:00	Case2	4.497	22.675	5.649
7:00	Case2	3.959	20.58	5.49
8:00	Case 1	3.942	20.395	5.738
9:00	Case 3	3.775	19.383	6.251
10:00	Case2	3.514	17.637	6.311
11:00	Case2	3.509	17.591	6.567
12:00	Case 1	3.983	19.795	6.075
13:00	Case2	3.771	19.496	5.979
14:00	Case 1	3.724	19.06	6.358
15:00	Case 1	3.81	19.831	5.815
16:00	Case 1	3.51	17.715	6.145
17:00	Case 3	3.807	19.472	6.195
18:00	Case2	3.833	19.657	6.014
19:00	Case 1	3.952	20.425	5.71
20:00	Case 1	3.851	19.888	5.816
21:00	Case 3	3.918	19.591	5.794
22:00	Case 3	3.827	19.87	5.614
23:00	Case2	4.173	21.701	5.34
24:00:00	Case 3	4.735	23.142	5.542

Table 6: Comparison of Per Unit Voltage with and without DGs Unit

1:00AM			
W/O DG	Case 1	Case 2	Case 3
0.962	0.976	0.987	0.976
0.956	0.989	1.017	0.989
0.969	0.977	0.983	0.977
0.967	0.975	0.981	0.975
0.964	1.001	0.991	0.991
0.961	1.013	1	1
0.961	0.998	0.977	0.998
0.956	1.005	0.976	1.005

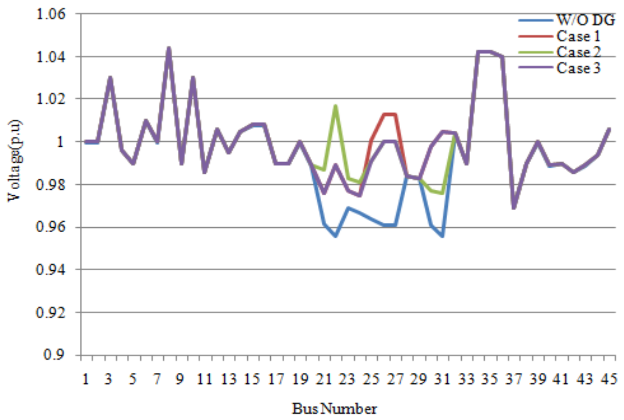

Figure 8: Comparison of Per Unit Voltage

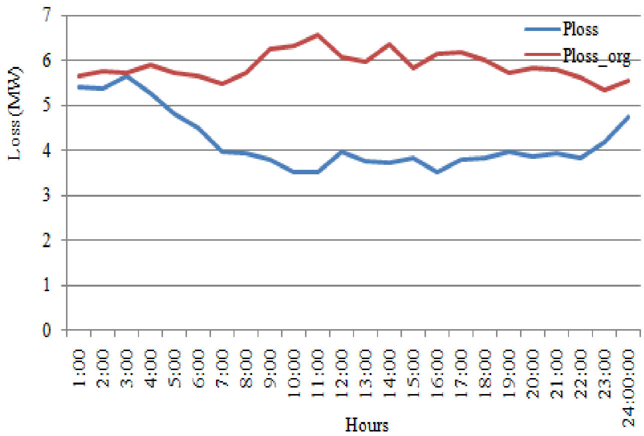

Figure 9: Comparison of Losses

2.5 Reliability Indices

The sample calculation of radial distribution circuit contains three load points with total load capacity of 15.24MW and total customers connected with system were 43729 customers. Initially all the reliability parameters were calculated for the base case and then the disconnecting switches are connected with load points B, C and D and again all parameters were calculated. Now in case 1, 2 and 3, a DG of capacity 10, 10 and 35MW were connected at the poor bus voltage buses and again all the reliability parameters were calculated.

Table 7: Load Point Indices for Base Case (for bus 31)

Load Point	λ (failure/yr)	r (Hrs)	U (Hrs/yr)
B	1.052	2.563	2.696
C	1.052	2.572	2.706
D	1.052	3	3.156

Table 8: Load Point Indices for Case1 and 2 (for bus 31)

Load Point	λ (failure/yr)	r (Hrs)	U (Hrs/yr)
B	1.052	0.131	0.138
C	1.052	0.129	0.136
D	1.052	0.053	0.055

Table 9: Load Point Indices for Case 3 (for bus 31)

Load Point	λ (failure/yr)	r (Hrs)	U (Hrs/yr)
B	1.052	0.230	0.236
C	1.052	0.230	0.235
D	1.052	0.175	0.176

Table 10: Comparison of Reliability Indices for all Three Case (for bus 31)

Indices	Without DG	Case 1	Case 2	Case 3
SAIFI (int/cust/yr)	0.00007217	0.00007217	0.00007217	0.00007217
SAIDI (hrs/cust/yr)	0.0001957	0.00000752	0.00000752	0.00001479
CAIDI) (hr/yr)	2.7116603	0.1042458	0.1042458	0.2050063
ASAI (%)	0.99	0.99	0.99	0.99
ENS(MWh/yr)	130.42	5.014	5.014	9.86
AENS(MWh/yr)	0.00298	0.0001146	0.0001146	0.00022548

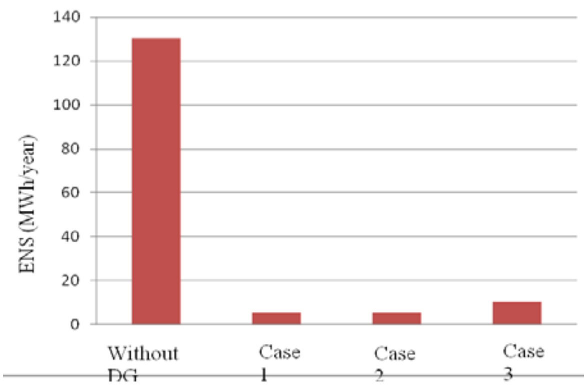

Figure 10: Comparison of ENS (for bus 31)

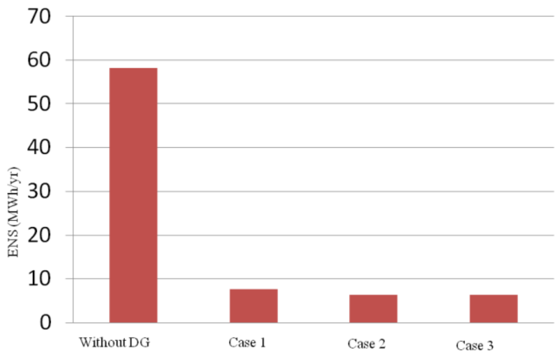

Figure 11: Comparison of ENS (for bus 26)

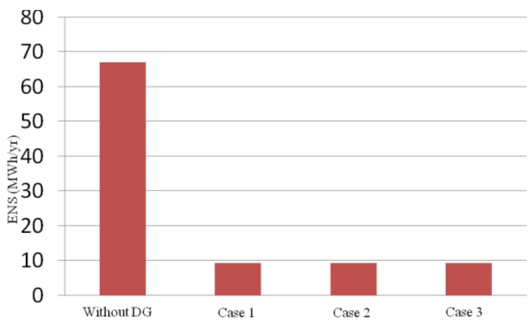

Figure 12: Comparison of ENS (for bus 22)

From the figure 10, 11 and 12, reliability improves is a good manner for system because of the penetration of DGs to the radial bus with appropriate location and size. As system reliability indices SAIFI and ASAI is not change but the indices of SAIDI, CAIDI and ENS are improved by case 1, 2 and 3. Availability of service is not increased. The indices of CAIDI, SAIDI, ENS and AENS will be decreased after putting the DG sources respectively.

3. Conclusion

In this paper, Fuzzy method was implemented by using MATLAB and was tested for a Yangon 66kv, 45-bus test system. This method was compared after connecting one DG, two DGs, and three DGs to the system at different load power values. The suitability indices improvement show the location of radial buses where the DGs should be introduced. By installing DGs at the radial buses, the total power loss of the system has been reduced drastically and the voltage profile of the system was also improved.

The calculation results of table-5 and 6 were showed that appropriate size and location of DG units will lead a significant role to minimize the losses in distribution system. The sample calculation of SAIFI, SAIDI, CAIDI, ASAI, ENS and AENS are presented as reliability indices when reliability improvement of Yangon distribution system was evaluated. In this system if the DG of more capacity reliability of system will improves more but cost of DG will much higher than service availability. Moreover, it was found that losses reduction and voltage profile improvement is more in the Yangon network by installing the DG units.

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