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Optimal Location and Sizing of DG using Fuzzy logic

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Abstract: *Introduction of distributed generation modifies the structure of power system network. High levels of penetration of distributed generation (DG) are new challenges for traditional electric power systems. A power injection from DG units modifies network power flows, changes energy losses and improves voltage profile of the system. Proper locations of DG units in power systems are very important in order to obtain maximum potential advantages. There are some of the most popular DG placement methods, such as Optimal Power Flow, 2/3Rule and Evolutionary Computational Methods. The Evolutionary computational method includes Genetic Algorithm, Fuzzy Systems and Tabu Search. In this paper we have considered the Fuzzy logic method for the optimal location and sizing of DG.*

The optimal placement of DG is necessary to improve the reliability and stability. Proposed method is tested by considering IEEE 33bus system data. The Fuzzy logic method includes a fuzzy inference system (FIS) containing a set of rules which are considered to determine the DG placement suitability index of each node in the distribution system. The optimal sizing of DG unit is obtained with the help of mathematical expressions.

Keywords: *Distributed Generation (DG); Fuzzy logic; Fuzzy rule; Optimal Location; Optimal Power flow.*

I. Introduction

Distributed generation is defined as small scale generation which is not directly connected to the bulk transmission system & it is not centrally dispatched. Distributed generation is connected at the distribution level which leads to the many changes in the characteristics of distribution network. The proper location of DG plays a very important role to upgrade the system reliability and stability, to reduce the system losses, to improve the system voltage profile [1].At present the number of scholars are carry the work on placement of DG here the reference [2] considers the case of single radial feeder with the three load conditions namely uniform load, concentrated load, increasing load for which the optimal location of DG is found with the analytical approaches to minimize the losses in the single radial feeder. The optimal location of DG is needed to increase the distributed generation potential benefits in the power system. There are many methods for the proper location and sizing DG, some of the methods are explained in reference [3]. Such as Evolutionary computational method [including genetic algorithm, fuzzy logic, & tabu search], 2/3 Rule, optimal power flow. Reference [4] shows the consideration of Fuzzy rules for the proper location of capacitor. In case of Fuzzy logic a set of Fuzzy rules are considered for the proper placement of DG by considering the VSI and PLI as a input to the system and output as DGSI. The mathematical equations are used to calculate the sizing of DG [5].

India is world's 6th largest energy consumer, accounting for 3.4% of global energy consumption. Due to India's economic rise, the demand for energy has grown at an average of 3.6% per annum over the past 30 years. In March 2011, the installed power generation capacity of India stood at 173,000MW. The country's annual power production increased from about 190 billion kWH in 1986 to more than 680 billion kWH in 2006. The Indian government has set an ambitious target to add approximately 78,000MW of installed generation capacity by 2012. The total demand for electricity in India is expected to cross 950,000 MW by 2030.

Electricity losses in India during transmission and distribution are extremely high and vary between 30 to 45%. In 2004-05, electricity demand outstripped supply by 7-11%. Due to shortage of electricity, power cuts are common throughout India and this has adversely effected the country's economic growth. However, due to lack of adequate investment on transmission and distribution (T&D) works, the T&D losses have been consistently on higher side, and reached to the level of 32.86% in the year 2000-01.The reduction of these losses was essential to bring economic viability to the State Utilities

A key factor when implementing DG is the underlining technology. Technologies can be separated in generation and storage. Generation is further divided into conventional and nonconventional. Conventional includes combustion turbines, diesel engines, micro-turbines and natural gas engines. Non-conventional are mostly renewable energy technologies.

Table 1 Distributed Generation Technologies

Technology	Typical available size per module
Combined cycle gas T.	35–400 MW
Internal combustion engines	5 kW–10 MW
Combustion turbine	1–250 MW
Micro-Turbines	35 kW–1 MW
Micro hydro	25 kW–1 MW
Wind turbine	200 Watt–3 MW
Photovoltaic arrays	20 Watt–100 kW
Biomass, e.g. based on Gasification	100 kW–20 MW
Fuel cells, phosacid	200 kW–2 MW
Fuel cells, molten carbonate	250 kW–2 MW
Fuel cells, proton exchange	1 kW–250 kW
Battery storage	500 kW–5 MW

II. Introduction To Fuzzy Logic

In Fuzzy Logic Toolbox™ software, fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in Foundations of Fuzzy Logic. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution.

Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL.

Table.2 Index with DG and without DG by index values

Bus No	With DG		Without DG		INDICES	
	P loss in MW	Q loss in MVAr	P loss in MW	Q loss in MVAr	ILP	ILQ
K=2	0.8117	1.6267	1.1332	2.2708	0.38371	0.283645
K=3	2.2714	4.5451	2.8999	5.8021	0.316732	0.216646
K=4	1.8442	3.6893	2.6604	5.3218	0.306796	0.306757
K=5	1.9724	3.9464	2.8999	5.8021	0.319839	0.319832
K=6	1.6569	3.3144	2.6604	5.3218	0.377199	0.377203
K=7	1.8644	3.7301	2.8999	5.8021	0.357081	0.357112
K=8	1.6245	3.2493	2.6604	5.3218	0.389378	0.389436
K=9	1.8168	3.6347	2.8999	5.8021	0.373496	0.373554

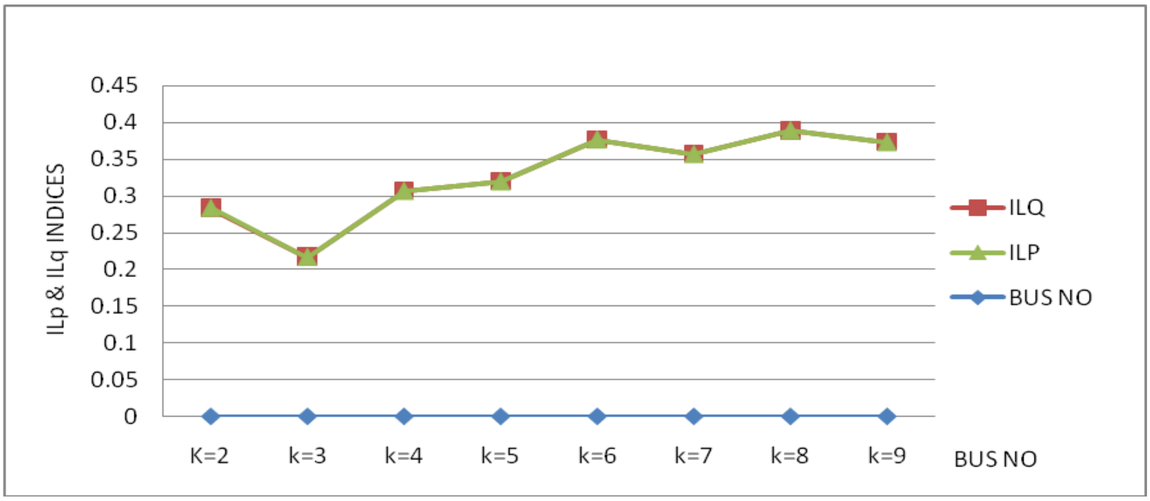
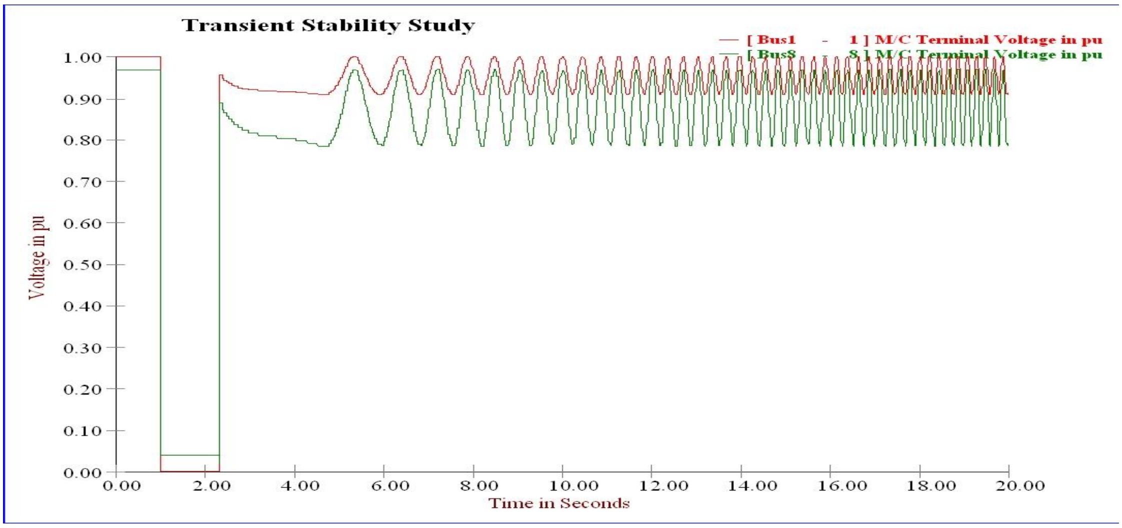


Fig.1 Graph of Total Multi objective index



Fig,2 Generator terminal voltage of DG w.r.t. Grid (1-2.34sec

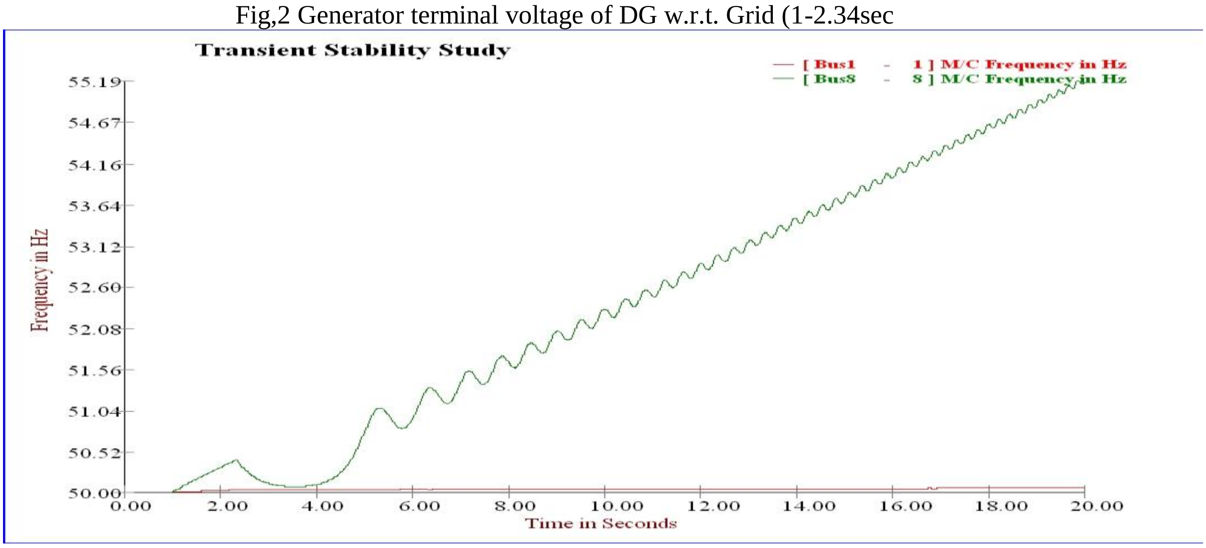


Fig.3Frequency of DG w.r.t. Grid (1-2.34sec)

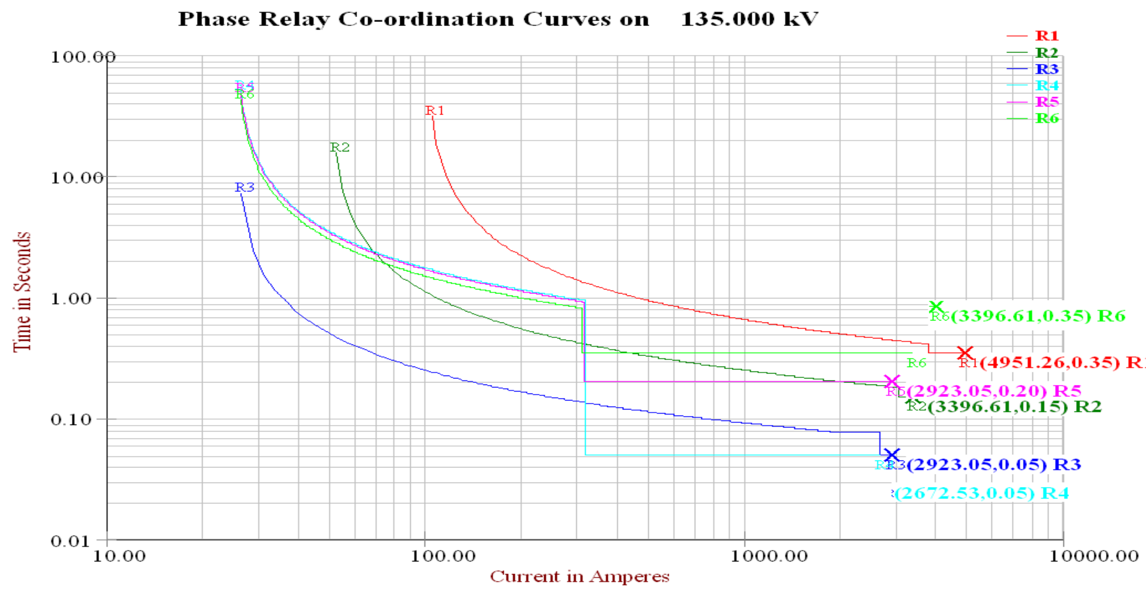


Fig.4 Relay co-ordination

III. Determination Of Sensitive Buses For The Optimal
IV. Location Of Dg For 33bus System

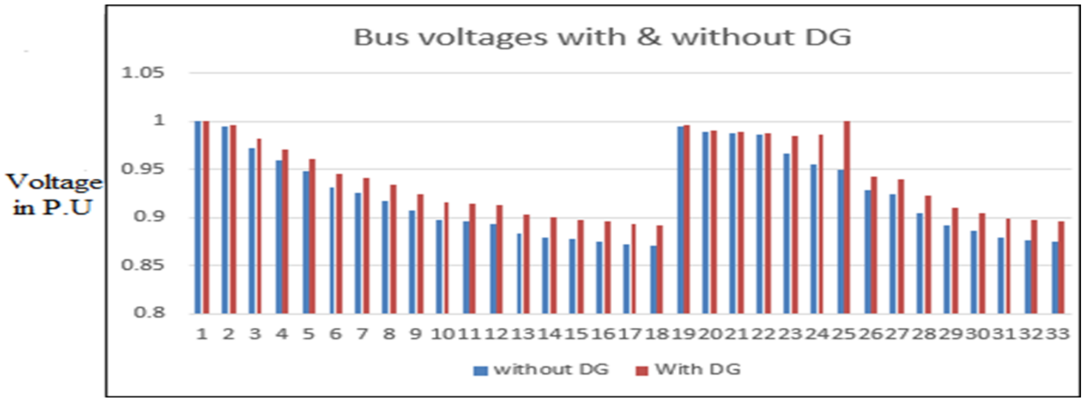
The connection of DG unit in the feeder drastically reduced the total feeder losses as compared to the feeder without DG. But it is not an easy task to implement the DG directly into a feeder. It requires an optimal placement where there is minimum loss and also improvement in voltage profile, since for each and every position of DG connection the losses and voltage profile were different.

Improvement Of Voltage Profile With DG

Bus No	Without DG Voltage in P.U	With DG Voltage in P.U
1	1.0000	1.0000
2	0.9952	0.9968
3	0.9725	0.9826
4	0.9601	0.9714
5	0.9479	0.9604
6	0.9317	0.9461
7	0.9259	0.9409
8	0.9178	0.9337
9	0.9074	0.9244
10	0.8976	0.9159
11	0.8962	0.9146
12	0.8937	0.9124
13	0.8835	0.9034
14	0.8797	0.9001
15	0.8773	0.8980
16	0.8750	0.8960
17	0.8716	0.8931
18	0.8706	0.8922
19	0.9944	0.9959
20	0.9886	0.9903
21	0.9875	0.9891
22	0.9864	0.9881
23	0.9667	0.9844
24	0.9558	0.9866
25	0.9504	1.000

26	0.9285	0.9432
27	0.9242	0.9394
28	0.9051	0.9226
29	0.8914	0.9104
30	0.8855	0.9052
31	0.8785	0.8991
32	0.8770	0.8977
33	0.8755	0.8964

Table3 Bus voltages with & without DG



Bus no

Fig 4 Bus voltages with & without DG

V. Procedure To Calculate The Optimal Size Of DG

First let us consider the drawn system diagram in which the DG is placed at the bus i, which produces the current of I_{DG}. In a radial distribution system the current I_{DG} changes for the current branches which are connected to bus i, where as the current of other branches are unchanged.

Therefore new current Ik' of the k^{th} branch is given by

$$Ik' = Ik + AkI_{DG} \tag{1}$$

Where A_K=1 if K^{th} branch which is connected to bus i otherwise Ak=0

The value of current I_{DG} can be calculated with the help of fallowing equation

$$I_{DG} = -\left[\frac{\sum_{k=1}^{nbus-1}(AkIkRk)}{\sum_{k=1}^{nbus-1}(Ak)^{\wedge}2Rk}\right] \tag{2}$$

Now the size of DG is calculated by considering the fallowing equation

$$S_{DG} = ViI_{DG} \tag{3}$$

Where Vi=Voltage at the i^{th} bus

VI. Conclusion

In this paper we have considered optimal location & sizing of DG using Fuzzy logic. Optimal location of DG is optained using Fuzzy logic and optimal size of DG is calculated by analytical method which are helpful to upgrade the loss minimization and improvement of voltage profile. Finally we can conclude that proper location & sizing of DG is better to improve the voltage profile, reduction in the losses and helps to improve the overall system stability.

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APPENDIX

IEEE 33 Bus system

A. Line data for IEEE 33 Bus system

BASE: 12.66 kV, 100MVA

Sending bus	Receiving bus	R (in ohm)	X (in ohm)
1	2	0.09220	0.04700
2	3	0.49300	0.25110
3	4	0.36600	0.18640
4	5	0.38110	0.19410
5	6	0.81900	0.70700
6	7	0.01872	0.61880
7	8	0.71140	0.23510
8	9	1.03000	0.74000
9	10	1.04400	0.74000
10	11	0.19660	0.06500
11	12	0.37440	0.12380
12	13	1.46800	1.15500
13	14	0.54160	0.71290
14	15	0.59100	0.52600
15	16	0.74630	0.54500
16	17	1.28900	1.72100
17	18	0.73200	0.57400
2	19	0.16400	0.15650
19	20	1.50420	1.35540
20	21	0.40950	0.48740
21	22	0.70890	0.93730
3	23	0.45120	0.30830
23	24	0.89800	0.70910
24	25	0.89600	0.70110
6	26	0.20300	0.10340
26	27	0.20420	0.14470
27	28	1.05900	0.93370
28	29	0.80420	0.70060
29	30	0.50750	0.25850
30	31	0.97440	0.96300
31	32	0.31050	0.36190
32	33	0.34100	0.53020

B. Load data for IEEE 33Bus system

Bus No	Bus code	Load Data	
		K W	KVAR
1	1	-	-

2	0	100	60
3	0	90	40
4	0	120	80
5	0	60	30
6	0	60	20
7	0	200	100
8	0	200	100
9	0	60	20
10	0	60	20
11	0	45	30
12	0	60	35
13	0	60	35
14	0	120	80
15	0	60	10
16	0	60	20
17	0	60	20
18	0	90	40
19	0	90	40
20	0	90	40
21	0	90	40
22	0	90	40
23	0	90	50
24	0	420	200
25	0	420	200
26	0	60	25
27	0	60	25
28	0	60	20
29	0	120	70
30	0	200	600
31	0	150	70
32	0	210	100
33	0	60	40