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Comparative Analysis of Optimization Method: Smart Grid Case Study

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Abstract: Distributed generation (DG) are small scale power producers close to end user of power. This is having are many technical, economic and environmental benefits. By appropriate placement of DGs at optimum location with optimum size, benefits of DG can be maximized. In this paper the optimal capacity of distributed generation (DG) plant in a microgrid is determined to minimize the cost function. Two different cases are considered to solve the cost function. In first case it is assumed that installation cost of DG unit is stable and based on the constraints of the capacity limit of DG, linear mathematical model is developed. Here the method is applied on diesel, wind and solar power unit. In second case uncertainty is considered in installation cost of DG. To deal with this uncertainty fuzzy logic is used and membership function made which defuzzified by three different methods and converted into linear mathematical programming. And both the cases are compared and found that FLP is better than simple linear programing.

Keywords: Distributed generation (DG), Microgrid (MG), Fuzzy linear programming (FLP), Linear programming (LP), Defuzzification

I. INTRODUCTION

The optimum size and location of DG units in the area of the load causes a decrease in losses on the power networks and also the thermal losses at the power station and improves voltage profile [1], [2]. The generation sources powered by renewable resources are of great worth in MG, which holds DG along with other components. In actuality, as such generation sources provides end consumers a better power quality, let provision of higher reliability electric service, and decrease pollutant levels [3], [4]. It helps to reduce greenhouse gas emission. There has been a wide range of modular size from 5 KW to 500 MW [5]. Table 1 shows the available DG modular sizes. Storage devices, such as flywheels and batteries are used in improving the efficiency and stability of MG [6], [7].

The Control of frequency and voltage is done by local controllers. These controllers control inverters to produce the active power needed by demand side. It is to establish equilibrium between production and consumption [8], [9]. MGs central controller (MCC) determines the set point for each local controller. And MCC is controlled by the MGs operating system [10], [11].

In practical problem, the maximum time the information is indefinite. To deal this uncertainty fuzzy logic was introduced. Linear programming is one of most used techniques in operation research. Membership function (MF) developed and various methods can be used to defuzzify it. MF can be of triangular shape, square, trapezoidal, depends on input quantity [12].

In this paper, focus is to find the optimal capacity of DG plant in a micro-grid to minimize the cost function. Two different cases are taken to determine the cost function. In first case it is assumed that installation cost of DG system is fixed and on the basis of the constraints on the DG's capacity limit, linear mathematical model is developed. Here the method is applied on wind, diesel and solar power unit. In second case uncertainty of installation cost of DG has been involved. To deal with uncertainty fuzzy logic tool is used and membership function are generated which defuzzified by different methods and converted into linear mathematical programming.

TABLE I. DG MODULAR SIZE [5]

SI no.	DG technology	Available power module size
1	Combined cycle gas turbines	35-400 mw
2	Internal combustion engines	5kw-10 mw
3	Combustion turbine	1-250 mw
4	Micro-turbine	35kw -1 mw
5	Fuel cells	200kw-2 mw
6	Battery storage	0.5-5 mw
7	Hydro power	1-25 mw
8	Wind turbines	200w-3 mw
9	Solar pv	20 w -100 kw
10	Solar thermal power plant	1-10 mw
11	Biomass gasification based	100kw-20 mw
12	Ocean energy	0.1-1 mw

II. PROBLEM STATEMENT

To determine the optimal capacity of wind power unit, diesel power unit and solar power unit under normal and fuzzy environment to minimize the cost function, two cases are considered. Some assumptions have been made to frame the model into mathematical form. The First case is to frame the linear mathematical problem while second

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case leads to the fuzzy linear programming problem. Assumption while framing the model is given below for different case.

A. Problem statement I

- Numbers of unit of DG is single.
- Electricity Price of is fixed.
- All three units should generate at least 1MW unit of power.
- Each plant should generate at least some electricity.
- Diesel engine should generate power at least twice of combination of wind and solar plant.
- Each plant must generate some least define amount of power and we kept varying minimum limit of generation of power.

B. Problem statement II

- Electricity Price of is uncertain.
- All other condition are same as case i

III. METHODOLOGY

To solve case I linear programing is used to frame and solve mathematical model, while case II is solved using fuzzy logic. By which mathematical model is framed. The fuzzy logic phases is shown in Fig 1

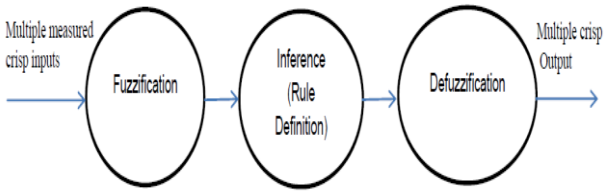

Fig 1. Fuzzy Logic Phases

IV. ASSOCIATED COST OF DG's PLANT

R. Banerjee and A. Nayak reviewed the different technological options available for DG; their current status and evaluated them based on the generation cost and India's future potential [6-7] .The generation cost is dependent on load factor and discount rate. It includes cost of operation and maintenance. Installation cost for different plant taken in Rs / KW and as follows

1. Cost of wind power generator (C_w) =50,000 Rs /kW
2. Cost of diesel power generator (C_c) = 25000 Rs /kW
3. Cost of solar power generator (C_s) =144,000 Rs/kw

V. MATHEMATICAL MODEL

Based on the given problem statement objective function and subject to constraints are made and framed in mathematical form which are given below.

Objective function- here objective is to minimize the cost function. Cost coefficients of the objective function are crisp value i.e. single valued [13]. Mathematically objective function can be represented as-

$$Min\ \Sigma(C_w X_w + C_c X_c + C_s X_s)$$

Subject to constraints

1. $X_w + X_c + X_s \geq 1000kW$
2. $X_w \geq 100kW$
3. $X_c \geq 100kW$
4. $X_s \geq 100kW$
5. $X_w + X_s \leq 0.5X_c$

Where

C_w: cost of wind power generator (Rs/kw)
C_s: cost of solar power generator (Rs/kw)
C_c: Cost of diesel engine generator (Rs/kw)
X_w: Capacity of wind power generator unit (kW)
X_s: Capacity of solar power generator unit (kW)
X_c: Capacity of diesel power generator unit (kW)

VI. MEMBERSHIP FUNCTION

Figure 2,3,4 represents membership function of Wind, Solar and Diesel Power Plant respectively. It is required to solve the linear programing using simplex method. Cost range of wind power plant is from Rs 48000 to Rs 52000 where membership function is 1 from 48000 to 50000 and decreases continuously and becomes 0 at 52000. Similarly Cost range of solar and diesel power plant range from Rs 142000 to Rs 146000 and Rs 23000 to Rs 27000 respectively. Their membership function remains 1 up to 145000 and 25000 respectively and becomes 0 at 146000 and 27000 respectively

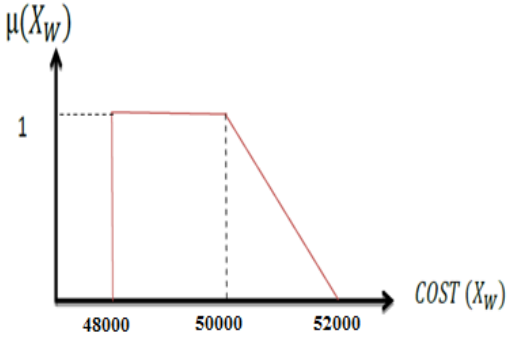

Figure:2 Wind Power Plant

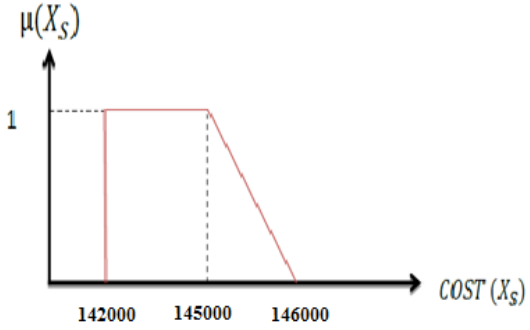

Figure:3 Solar Power Plant

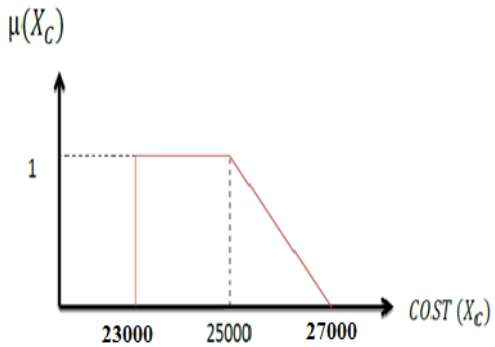

Figure:4 Diesel Power Plant

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VII. RESULT

Table 2 represents Optimal Capacity of DG using Linear Programing for problem statement 1.Simplex algorithm is used to find the capacity of DG plant. Optimum Capacity and minimum cost are shown in tabular form for different generation capacity. From the table it can be witnessed that optimal capacity of diesel engine is highest among three and optimal capacity of solar and wind are minimum of its generation capacity. And also as the capacity of each DG unit is increased optimal value is also increased in the same proportion for wind and solar plant, but diesel plant produces large power since it involves less cost. So it is increases in large proportion.

TABLE II. OPTIMAL CAPACITY OF DG USING LINEAR PROGRAMING

S. No.	(X) Capacity (kW) (X 100)			(X) Optimal Value (kW) (X 100)			Minimized Cost (Rs) (X 10^5)
	W	S	C	W	S	C	
1	1	1	1	1	1	8	394
2	2	1	1	2	1	7	419
3	3	1	1	3	1	8	494
4	1	2	1	1	2	7	513
5	2	2	1	2	2	8	588
6	1	3	1	1	3	8	682
7	3	2	1	3	2	10	688
8	2	3	1	2	3	10	782
9	3	3	1	3	3	12	882

For problem Statement 2 table 3 represents defuzzified values which are obtained after defining membership function and different techniques by this we can get modified objective function for different techniques which can be solved by simplex algorithms.

TABLE III. DEFUZZIFIED VALUE FOR DG

Source	Price Range	Centroid	Max Mean Method
Wind	48000-52000	49530	49000
Solar	142000-146000	143530	143000
Diesel	23000-27000	24530	24000

Table 4 represents optimal capacity of DG with fuzzy objective using mean-max method for problem statement 2.Here mean max method is used in defuzzification to get the objective constraint after that Simplex algorithm is used to find the capacity of DG plant. Comparing FLP and LP we can see that FLP gives better result. Optimum Capacity and minimum cost are shown in tabular form for different generation capacity. From the table it can be witnessed that optimal capacity of diesel engine is highest among three and optimal capacity of solar and wind are minimum of its generation capacity. And also as the capacity of each DG unit is increased optimal value is also increased in the same proportion for wind and solar plant, but diesel plant produces large power since it involves less cost. So it is increases in large proportion.

Table 5 represents optimal capacity of DG with fuzzy objective using centroid method for problem statement 2.Here centroid method is used in defuzzification to get the objective constraint after that Simplex algorithm is used to find the capacity of DG plant. Comparing FLP and LP here also we can see that FLP gives better result. And out of centroid and mean max method, mean max method gives better result. Optimum Capacity and minimum cost are shown in tabular form for different generation capacity. From the table it can be witnessed that optimal capacity of diesel engine is highest among three and optimal capacity of solar and wind are minimum of its generation capacity. And also as the capacity of each DG unit is increased optimal value is also increased in the same proportion for wind and solar plant, but diesel plant produces large power since it involves less cost. So it is increases in large proportion.

TABLE IV. OPTIMAL CAPACITY OF DG WITH FUZZY OBJECTIVE USING MEAN-MAX METHOD

S. No.	(X) Capacity (kW) (X 100)			(X) Optimal Value (kW) (X 100)			Minimized Cost (Rs) (X 10^5)	
	W	S	C	W	S	C	FLP (max mean)	LP
1	1	1	1	1	1	8	384	394
2	2	1	1	2	1	7	409	419
3	3	1	1	3	1	8	482	494
4	1	2	1	1	2	7	503	513
5	2	2	1	2	2	8	576	588
6	1	3	1	1	3	8	670	682
7	3	2	1	3	2	10	673	688
8	2	3	1	2	3	10	767	782
9	3	3	1	3	3	12	864	882

TABLE V. OPTIMAL CAPACITY OF DG WITH FUZZY OBJECTIVE USING CENTROID METHOD

S. No.	(X) Capacity (kW) (X 100)			(X) Optimal Value (kW) (X 100)			Minimized Cost (Rs) (X 10^5)	
	W	S	C	W	S	C	FLP (Centroid)	LP
1	1	1	1	1	1	8	389.3	394
2	2	1	1	2	1	7	414.3	419
3	3	1	1	3	1	8	488.36	494
4	1	2	1	1	2	7	508.3	513
5	2	2	1	2	2	8	582.36	588
6	1	3	1	1	3	8	676.36	682
7	3	2	1	3	2	10	680.95	688
8	2	3	1	2	3	10	774.95	782
9	3	3	1	3	3	12	873.54	882

VIII. CONCLUSION

Two different approaches have been applied to find the optimum capacity of DGs so as the cost function is minimized. Initially LP was used to find the capacity, from the result of LP problem, it can be concluded that diesel engine have to generate most of the power in order to minimize the cost function whereas since cost of solar and wind are high hence it have generate less power that is shown in the result. FLP problem with fuzzy objective function is studied in which price of electricity was uncertain. From the result we can judge that different

defuzzification techniques will give same optimal value, as it is depends on membership function. Max mean method gives improved optimal value among other methods and also FLP method gives better optimal value over LP method.

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