SIMULTANEUS PLACEMENT OF CONVENTIONAL AND RENEWABLE DISTRIBUTED GENERATION USING FUZZY MULTIOBJECTIVE OPTIMIZATION

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ABSTRACT

This paper proposes fuzzy multi objective optimization to determine the optimal size and location of conventional and renewable distributed generation in distribution network. In this paper the random generation of renewable DG is represented with a probabilistic-fuzzy approach. Operating constraints in DG placement are considered and the amount of ENS and current/voltage constraints evaluated using by fuzzy load flow. Objective function consists of ENS, economical advantage of DG's and also environmental benefits of renewable based DGs.

INTRODUCTION

Distributed generation (DG) has an important role in power distribution system planning because of its modularity, small size and low investment cost. Due to environmental concerns, DG sources can be placed in distribution networks for grid reinforcement, voltage profile improvement, reducing the risk of overloading the distribution feeders and investments deferral [1]. Moreover, some system characteristics such as reliability and power losses will be improved if these resources Accurately allocated and correctly determine the capacity in distribution systems [2]. Application of renewable energy in supply of electrical energy due to environmental issues and saving fossil fuel consumption is developing day to day. on the other hand, some uncertainties of renewable generation, such as the stochastic output power of a wind turbine due to the frequently variable wind speed, a solar generating source due to the stochastic illumination intensity and future uncertain load growth could lead to some risk in determining the optimal sitting and sizing of DGs in distribution system planning[3]. In recent years, several studies have considered techniques based on network characteristics and type of generation and load modelling, for locating DG units on distribution system [2]. According to the above description, in this context a novel strategy for simultaneous conventional and renewable distributed generations is presented based on fuzzy multi objective programming. Adequate supply, reliability and voltage of distribution system are considered as the optimization constraints. The proposed methodology is implemented in a real network and the results are presented to demonstrate its effectiveness.

PROPOSED METHOD

In this paper the random generation of renewable DG is represented with a probabilistic-fuzzy approach, in which first a probability density function is utilized with uncertain wind speed modeling. The wind speed probability density function is converted to possibilistic distribution function thus presented in fuzzy form. All operating constraints of DG placement are considered and the amount of energy not supplied (ENS) and current/voltage constraints are evaluated running fuzzy power flow. All terms of objective function are calculated using fuzzy theory concepts and probabilistic approach. NSGA-II as a multi objective optimization procedure is used for determining the pareto optimal solutions. Objective function consist of system distribution system adequacy index (load not supplied), economical advantage of distributed generations as well as environmental benefits of renewable based DGs. The proposed method based ona fuzzy multi-objective model is shown in Fig.1.

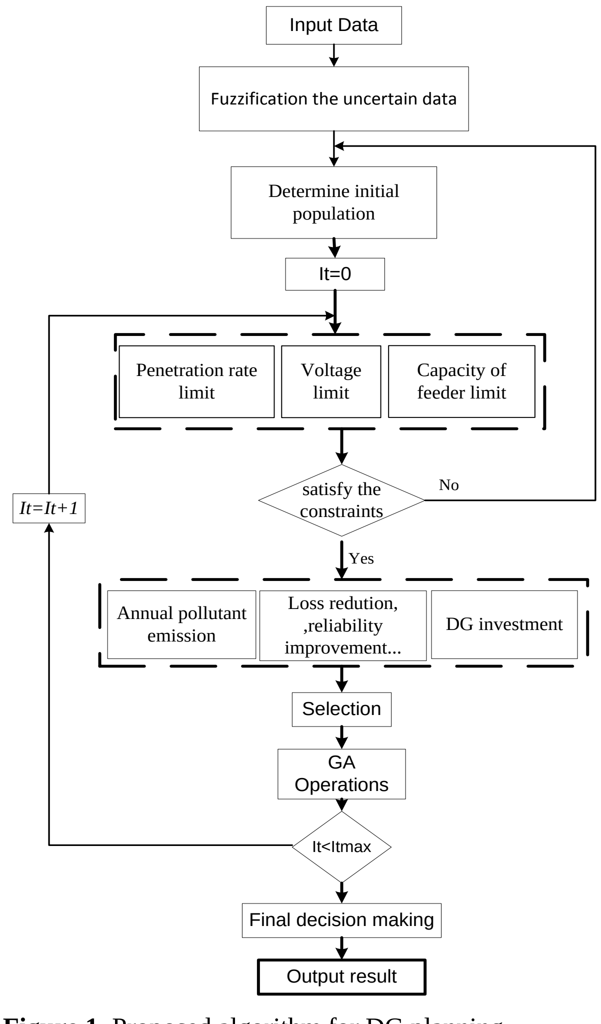

Figure 1. Proposed algorithm for DG planning

MODELLING OF LOAD AND GENERATION

In this section, modeling of load and power generation of renewable based DG is explained.

Load modelling

Load in distribution networks can vary with time over a wide range and can be stochastic in nature. Because the results of load estimation and load forecasting techniques are not exact, it is desirable to find a suitable approach for consideration of load uncertainty in distribution system analysis. Fuzzy representation of a typical load duration curves (LDCs) and approximated of this with piecewise curves are shown in figure 2[4].

Generation modeling

Distributed generation can be divided into two clusters: conventional and renewable. Conventional generations such as gas turbine and diesel turbine have deterministic output and on the contrary, availability constraints of renewable energy resources such as wind turbine have stochastic nature that we assume as fuzzy numbers. The triangular fuzzy numbers (TFN) are defined based on three values: optimistic (P1), possible (P2) and pessimistic (P3) values as shown in figure3.

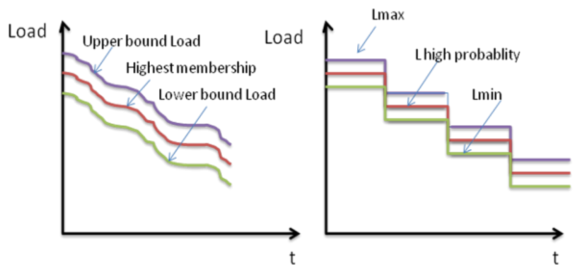

Figure 2. Typical and piecewise load duration curves

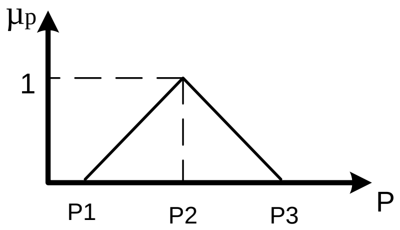

Figure 3. Fuzzy membership function of wind power availability equality

PROBLEM FORMULATION

In this section, the DG placement problem in a distribution system is formulated as a constrained multi-objective optimization problem where power losses, distribution system adequacy index (ENS), environmental issue, voltage profile index and DG investment cost (installation and maintenance) are optimized.

Objectives

1- Loss reduction

The high penetration of DGs can cause reduction in losses through generate electrical power near the loads and gets lower electric power from transmission grid. Loss reduction based on presence of DG can be formulated as following equation:

$$LRC = \sum_{t=1}^{hyear} \sum_{h=1}^{h=8760} \left(P^{DG0}_{loss,h} - P^{DG}_{loss,h}\right) \times C^h \times d^t \qquad (1)$$

$$d = \frac{1+\inf\ R}{1+\mathrm{int}\ R} \qquad (2)$$

Where, P^{DG0} is network loss at hour-h without considering DG in network (MW), P^{DG} is network loss at hour-h when considering DGs in network buses 1 to *n*, C^h is electricity market price at h-hour($/kWh) , *infR* is the annual inflation rate, *intR* is the annual interest rate, *LRC* is the cumulative present cost of power loss reduction during the planning horizon and *d* and: the economical factor. Using this factor, future cash flow rate can be transformed to present value.

2- Reliability improvement

Customer's outages, Imposes two costs to the electrical utilities: energy not supplied for affected customers and Cost of penalty due to regulation rules. Reliability calculation based on failure rate and repair time data that we can assumed these data as fuzzy numbers. In this paper, for assessing the DG effect on system reliability, ENS is calculated as reliability index as shown in Eq(3).

$$\tilde{ENS} = \sum_{l=1}^{l=nb} \lambda_i . L_i .\left(\sum_{j\in island} LP_j . r_{switching} + \sum_{j\notin island} LP_j . \tilde{r}_{repair}\right) \quad ..(3)$$

Where *ENS* is the fuzzy energy not supplied, *Nb* is the number of branches, L_i is the length of branch i, λ_i is the failure rate of branch i and LP_j is the power of jth load point. Also, island is the set of load points that supplied with DG after fault location. $r_{switching}$ is the switching time and r_{repair} is the fuzzy presentation of fault repair time[2].

3- Emission modelling in cost function

The amount of emission from a fossil-based thermal generator unit depends on the amount of power generated by the unit. In the employed objective function, the annual amount of pollutant gas emissions is minimized (4).

$$C_E = CO_2 .t.Ef \qquad (4)$$

Where CO2 denote amount of pollution produced per hour,C_E is total cost of emission, *Ef* is the emission fined per each kg Co2.In this study *Ef* is 30$/ton.$CO_2$.

4- DG investment cost

This term of cost function including DG installation and maintenance costs.

$$C_I = \sum_{i=1}^{NN} C_{DGi}.IC_{DG} + \sum_{t=1}^{T} \overset{t}{d}\left[\sum_{i=1}^{i=NN}(C_{DGi.}OC_{DG})\right] \quad (5)$$

Where, *NN* the total number of network nodes, $C_{DGi.}$: the capacity of DG in the ith node (KVA), IC_{DG}: the DG investment cost ($/KVA), *T*: the horizon planning year, OC_{DG}: annual operating cost of DG ($/KVAlyear) [5].

5- Voltage profile enhancement

One of the main solution to improve feeder voltage profile is install adequate amount of DGs in strategically places. Due to uncertain generation of renewable DGs, the feeder's voltage will change in a specific range. Whereas in this study, renewable generation have been considered as fuzzy number, we assume the voltage variation in each feeder is fuzzy which is shown in figure 4 due to deviation from the rated voltage(1 p.u), the utilities are obliged to pay penalty to customers based on contract which signed with customers. The proposed penalty scheme is shown in figure5.

In the employed objective function, the annual amount of voltage deviation penalty is minimized (6).

$$C_v = \sum_{i=1}^{i=NN} f(V_i) \quad (6)$$

Where C_v is the penalty cost of voltage deviation, the V_i is *ith* node voltage and *f(Vi)* is penalty cost proposed penalty function.

OBJECTIVE FUNCTION

Final objective function value for renewable and conventional DG placement with consideration of available uncertainties is defined as follows :

$$\tilde{F} = LRC + \sum_{h=1}^{T} \overset{t}{d}\,.\tilde{ENS}.C^h + C_I + C_E + C_v \ldots \quad (7)$$

Where *F* is fuzzy cost function after DG installation due to power losses, ENS, emission issue and voltage profile as well as DG installation and operation cost.

In this paper voltage constraints at load points and loading limits in feeders are neglected. We suppose that if these constraints are violated, utilities use capacitor placement as more economical procedure rather than considering constraints effect on DG placement, because DG installation and operation cost is very high.

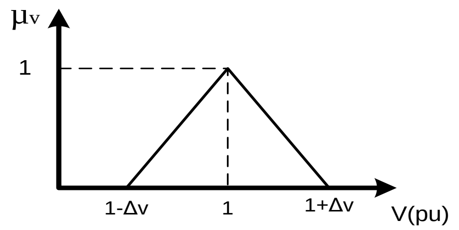

Figure 4. Fuzzy membership function for voltage deviation

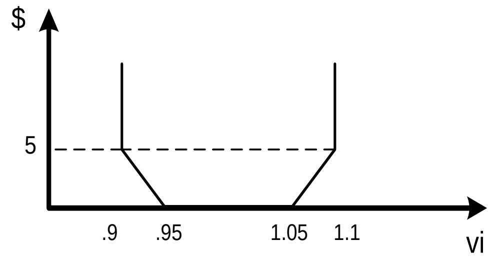

Figure 5. Proposed penalty scheme

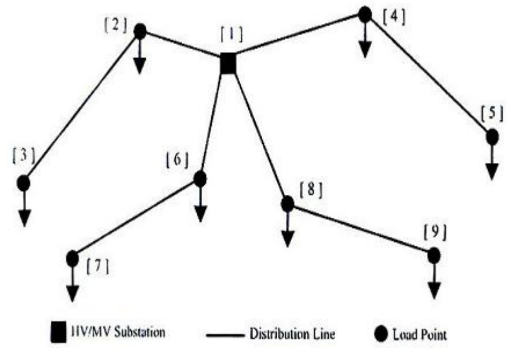

Figure 6. Distribution network under study

MULTI OBJECTIVE OPTIMIZATION ALGORITHM IMPLEMENTATION

In this study, to solve multi-objective optimization problem, NSGA-II is used to determine the decision variables such as size, location and technology's of DG. For this purpose, In the first step of program implementation, generate the random population, then for each population evaluate the value of objective function (that described in previous section), next, classify individuals into some layers according to the dominated concept and fitness of objective functions and non-dominate sort in the classified individuals in the same layer. After selection the precious population, execute cross-over and mutation operation and this process (except first step) repeated for the maximum iteration.

NUMERICAL RESULTS

The proposed approach for DG placement has been implemented in the MATLAB® and tested on primary distribution network studied in [6]. The test distribution network shown in figure 6 consists of one 132/33 KV substation of 75 MVA capacity to serve loads. With respect to operational limitations, maximum allowable loading of substation is considered as 50 MVA. Technical characteristics of conductors and future load data of the distribution network are given in [7]. Consideration of the cost data and some planning parameters are presented in Tables 1. The proposed NSGA-II has been executed with the following parameters: population size: 400, generation:

Table.1. Cost data used in the study

Parameter	Unit	Value
Horizon Year	Year	25
Operating Cost	$/MWh	WTG=8 DE=30
Market Price as TFN	$/MWh	(30,50,100)
Emission rate	kg/kWh	0.65
Failure rate	failure/yr/Km	(.01, .07, .18)
Repair Time	hour	(1, 1.5, 2)
Unit cost	$/kW	WTG=300 DE=1500
Installation cost	$/kW	WTG=600 DE=450

Table.3. Comparison of final soloution with initial condition

	Unit	Before install DG	After install DG
Power loss	kW	6118	1464
ENS	kWh	35.350	26.218

200, crossover probability: 0.9, and mutation probability is 0.15. In this paper, it is assumed that only diesel engine and wind turbine (WTG) can be used. The candidates diesel engine DGs have sizes of multiples of 0.5 MVA (maximum 3 MW) and wind turbine DGs have sizes of multiples of 0.2 MVA (maximum MW) with power generation at load factor of 0.9. Also the load growth is assumed as fix amount for any year in horizon.

The diffuzification of the aggregated objective function, given in done using removal function $R(\tilde{a})$ that for a TFN, $\tilde{a} = (a_L, a_M, a_R)$ describe as below:

$$R(\tilde{a}) = (a_L + 2a_M + a_R)/4 \qquad (8)$$

According to previous section, the final solution in the form of proposed sitting and sizing of DGs is shown in figure 7.
For illustrating the effects of DG placement, values of power losses and energy not supplied in the final solution as well as before DG installation are shown in Table 3.

CONCLUSION

This paper presented a new approach to determine the sizes, location and technologies of DGs based on fuzzy multi-objective model. This model covered different aspects of these technologies including economic, technical and environmental issues in a multi-objective represent. In this paper, uncertainties in renewable distributed generation, electricity market price, demand power, failure rates and repair times of equipments and hence reliability and voltage variation that considered for DG placement are modeled as fuzzy numbers.

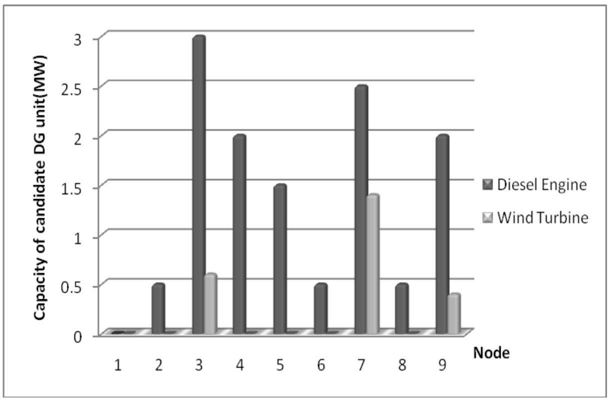

Figure 7. Final solution of DG placement

A specialized NSGA-II has been proposed as a solution algorithm and finally tested in a typical distribution network. These results show that DG placement in power distribution system can reduce power losses as well as energy not supplied.

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