Demand side management for Integration of Distributed Generators in distribution system based on cost and reliability analysis

[1]Subramanya k , [2]Dr. M.S. Nagaraj,
[1]Research Scholar, [2] Professor,
[1,2] Department of Electrical and Electronics,
[1, 2,] BIET, Davangere, India.

Abstract : Demand-side management has been an important element of the electric utility planning approach referred to as "integrated resource planning." A very important part of the demand-side management process involves the consistent evaluation of demand-side to supply-side alternatives and vice versa. This approach is referred to as "integrated resource planning." Distributed generation can serve as a supplement to electricity generated by huge power plants and delivered through the electric grid. Located at a customer's site, DG can be used to manage energy service needs or help meet increasingly rigorous requirements for power quality (PQ) and reliability. Technological improvements now allow power generation systems to be built to integrate DGs at power system to operate economically and to improve the system performance with the help of demand side management by considering the operational cost of the power system. In this paper analysis is carried out based on Economical and Reliability approach by considering a 42 bus radial test system using Matlab.

IndexTerms - Distributed Generation, Demand side management, Cost, Reliability indices, system performance .

I. INTRODUCTION

The problems of traditional energy shortage and environmental pollution are becoming more and more serious, and people pay more attention to renewable energy generation and demand side response mechanism. Demand side response mechanism is very important for integrated planning of power distribution network, especially the current large-scale access of DG. The price of the interruptible load is an important content of demand side response mechanism. The power companies and users signed the agreed price of interruptible load contract, and the power companies can cut off part of the users' load by making appropriate economic compensation.

Electricity shortages are exacerbated by inefficiencies mainly in end-use system. The inefficiencies in the end use system is due to irrational tariffs, technology obsolescence of industrial processes and equipment, lack of awareness, nascent energy services industry and inadequate policy drivers. The only value way in handling these crises is to overcome these inefficiencies in end uses that is possible with Demand Side Management Strategy [2]. Numerous studies in China and other countries have found that cost effective DSM programs can reduces the electricity use and peak demand by approximately 20-40% [3]. In India, great opportunities for reducing energy demand using DSM are available in all the sectors, many are low cost, or even individual can adopt them that help to reduce the electricity demand [4] and per unit generation cost, improving reliability and environment and social improvement.

Distribution network planning is a multi-objective integer programming problem, and with the addition of DSR and DG the planning dimension and the difficulty is increased. On the DG locating and capacity problem, an improved multi-objective harmony search algorithm is used to solve this optimization problem in [1]. In [2] the genetic algorithm is used to solve the optimization problem for minimizing system cost and maximizing DGs reliability. However, the power distribution network planning considering DG and DSR needs to be further studied.

II. OBJECTIVE FUNCTION

The planning objective function considers the investment and operation annual cost of DG, transmission loss cost, after integration of DG.

The optimization objective is follows [2] in this paper.

Min C = Canual + Closs + C DG ……………………………………2.1

where Canual is the annual loss cost, C DG is the investment and operation annual cost of DG, is the saving cost for purchasing electricity,

1) Annual loss cost: Canual = Cpu × ∑ki=1 (Ploss ×Lmax) …..2.2

where Cpu is the unit electricity selling price, k is the number of branches in the distribution system, Ploss is the active power loss of the i-th branch, Lmax is the annual maximum load loss hours of the i-th branch

Investment and operation annual cost of DG

$$C\,DG = \sum_{i=1}^{n\_DG} \left(\frac{a(1+a)m}{(1+a)m-1} \right) \times r_i \times P_{DGi} + W_{DGi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

Where n_DG is the number of DGs, a is the discount rate, m is the durable years of DG, ri is the unit capacity cost of DG in the i-th node, PDGi is the power capacity of DG in the i-th node. WDGi is the annual operation cost of DG in the i-th node.

Annual cost and saving for DG

$$Cb = \sum_{i=1}^{nDG} (P_{DGi} \times T_{DGi}) \times Cpb \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.4$$

Where T_{DGi} is the annual utilization hours of the i-th DG, Cpb is the unit feed-in tariff.

Constraints

1. The network constraints for equality are denoted utilizing the equations defining load flow [18]:

$$P_i(V,\delta) - P_{Gi} + P_{Di} = 0 \ldots\ldots\ldots\ldots\ldots\ldots 2.5$$

$$Q_i(V,\delta) - Q_{Gi} + Q_{Di} = 0 \ldots\ldots\ldots\ldots\ldots 2.6$$

$P_i(V,\delta)$ is real power with given voltage V and generator angle δ, P_{Gi} is the generated power , and P_{Di} is the demand at the i^{th} bus. Where $Q_i(V,\delta)$ is the reactive power with given voltage V and generator angle δ, Q_{Gi} is the generated reactive power , and Q_{Di} is the demand of reactive power in i^{th} bus. $P_i(V,\delta)$ and $Q_i(V,\delta)$ are defined as below,

$$P_i(V,\delta) = |V_i| \sum_{i=1}^{N} |V_i||Y_{ij}| \cos(\delta_i - \delta_j - \Phi_{ij}) \ldots\ldots 2.7$$

$$Q_i(V,\delta) = |V_i| \sum_{i=1}^{N} |V_i||Y_{ij}| \sin(\delta_i - \delta_j - \Phi_{ij}) \ldots\ldots 2.8$$

Where N is the number of buses and Φ_{ij} is the phase angle .The admittance is as defined in the following ,

$$Y_{ij} = |Y_{ij}| \angle \Phi_{ij}$$

2. Power flow constraints and load balance equations

$$P_{DGi} - P_{Li} = |V_i| \sum_{i=1}^{N} |V_i||Y_{ij}| \cos(\delta_i - \delta_j - \Phi_{ij}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.9$$

$$Q_{DGi} - Q_{Li} = |V_i| \sum_{i=1}^{N} |V_i||Y_{ij}| \sin(\delta_i - \delta_j - \Phi_{ij}) \quad \dots\dots\dots\dots\dots\dots 2.10$$

$$\sum_{i=1}^{N_G}((P_{Gi}) - \sum_{i=1}^{N_D}(P_{Di}) - P_L = 0 \dots\dots\dots\dots\dots\dots 2.11$$

where P_{DGi} and Q_{DGi} are the active and reactive power injections in the i-th node by DGs, P_{Li} and areQ_{Li} the active and reactive power load in the i-th node,

3. Installed capacity constraints of DG

$$0 \le SDGi \le Si$$

Where SDGi is the installed capacity of the i-th DG, Si is the maximum permissible installed capacity of the i-th DG.

4. The bounding conditions are defined by the constraints of inequality as given in the following

$$V_{imin} \le V_i \le V_{imax}, i = 1, \dots, N,$$

$$P_{Gimin} \le P_{Gi} \le P_{Gimax}, i = 1, \dots, N_G$$

$$Q_{Gimin} \le Q_{Gi} \le Q_{Gimax}, i = 1, \dots, N_{Gq}$$

Where V_{imin} and V_{imax} are the voltage limits in the i^{th} bus, P_{Gimin} and P_{Gimax} are the real power limits in the i^{th} generator, $Q_{Gimin}$and Q_{Gimax} are reactive power limits in the i^{th} generator

III. PROBLEM FORMULATION FOR RELIABILITY ANALYSIS

The reliability analysis is carried out based on the basic and standard performance indices, such as system average interruption duration index (SAIDI), system average interruption frequency index (SAIFI) and energy not supply index (AENS) in order to improve the system performance to improve the reliability of the power system.

The following basic equations are used for the calculation of load point reliability indices

$$\lambda L = \sum_{i=0}^{n} \lambda i \dots\dots\dots\dots\dots\dots 3.1$$

$$rL = \frac{\sum_{i=0}^{n} \lambda i * ri}{\sum_{i=0}^{n} \lambda i} \dots\dots\dots\dots\dots\dots 3.2$$

$$UL = \lambda L * rL \dots\dots\dots\dots\dots\dots 3.3$$

Where

i= feeder sections connecting the load points to the supply.

λl = Average failure rate at load point L

rL = Average outage time at load point L

UL= Average annual unavailability or average annual outage time at load point L

2.1 System Average Duration Index (SAIDI)

The average time of customers interrupted information can found by SAIDI

$$SAIDI = \frac{\sum_{i=0}^{n} Ui * Ni}{\sum_{i=0}^{n} Ni} \dots\dots\dots\dots\dots\dots 3.4$$

2.2 System Average Interruption Frequency Index(SAIFI)

It is the average number of interruptions per customer per unit time also defined as the ratio of a total number of interruptions to the total number of customers served.

$$SAIFI = \frac{\sum_{i=0}^{n} \lambda i * Ni}{\sum_{i=0}^{n} Ni} \dots\dots\dots\dots\dots\dots 3.5$$

2.3 Average Service Unavailability Index (ASUI)

It is the ratio of service availability of a total number of customer hours during a year to the customer hour demanded.

$$ASAI = \frac{\sum_{i=0}^{n} Ni*8760 - \sum_{i=0}^{n} Ui*Ni}{\sum_{i=0}^{n} Ni*8760} \quad \text{......3.6}$$

Where

Ni = number of customers at load point I, i=1, 2, 3, , , , , n

λi = failure rate at load point I, i=1,2,3,,,,, n

Ui = λ*r, where r is the outage time and 8760 is the number of hours in calendar year.

IV. RESULTS WITH ANALYTICAL EXAMPLE

A 42 nodes distribution network is used for the analysis in this paper, and the wiring diagram is shown in Fig. 1. The total length of all the lines is 26 km; the total number of users is 5974, including 7 industrial users, 2 power plant electricity loads, 5938 agricultural users or businesses users. The active failure rate of the 11 kV lines is taken as 0.0065f/yr-km, switching and repair time are assumed to be 1 and 5 hours respectively. Here we assume that the unit electricity selling price is 3.5 Rs/kWh, the unit feed-in tariff of thermal power plant is 8.5 Rs/kWh, the unit capacity investment cost of DG is 6300 Rs/kWh, the durable years of DG is 25 years, confidence level of voltage constraints α is 0.95.

Table 1 : Costs comparison with and without DG

Cost	Traditional planning without DG	Planning with DG	Percentage saving with DG
C	34319470	25636644	25.30 %
C loss	34319470	26690251	22.33 %
C DG	0	2304175	
Cb	0	2671150	

Table 2 : Reliability indices comparison with and without DG

Reliability Index	Traditional planning without DG	Planning with DG
SAIFI	4.6363	4.1232
SAIDI	13.2211	9.9898
ASAI	99.86	99.88

The total cost of the system operation got reduced by 25.3% with the integration of DG and the annual loss cost was reduced by 22.33%. The cost of DG and the saving cost for purchasing electricity are tabulated in table 1. The values of different reliability indices are before and after integration of DG are tabulated in Table 2.It is clear from the above two tables the demand side management has reduced the effective cost of the system with its operation.

V. CONCLUSION

The integrated planning model with DG is established in this paper, Integration of DGs using demand side management can avoid the conservative optimization results caused by deterministic constraints. Coding is done using Matlab to show that power flow calculation and also get achieve valid accuracy. The calculation results shows the saving of total cost of generation to serve different types of load points. The economy and reliability planning schemes are compared to show that the integrated planning with DG with demand side management can reduce the cost of network loss. Further the analysis can be carried out using different types of DGs with intermittent output characteristics and improve the reliability of power supply.

References

[1] Nekooei K, Farsangi M M, Nezamabadi-pour H, Lee K Y. An Improved Multi-Objective Harmony Search for Optimal Placement of DGs in Distribution Systems. IEEE Transactions on Smart Grid, 2013, (4)1: 557-567

[2] Tongdan Jin, Yu Tian, Cai Wen Zhang, Coit D W. Multicriteria Planning for Distributed Wind Generation Under Strategic Maintenance. IEEE Transactions on Power Delivery, 2013, 28(1): 357-367

[3] Rajan, C.C.A," Demand side management using expert system", IEEE Conference on Convergent Technologies for Asia-Pacific Region TENCON 2003.

[4] Padmanaban, S., Sarkar, Ashok," Electricity demand side management (DSM) in India – A Strategic and policy perspective", Office of Environment, Energy and Enterprise US Agency for International Development, New Delhi, India.

[5] Mukhopadhyay,S.,Rajput, A. K,Demand side management and load control. An Indian Experience", IEEE trans, on power and Energy Society General Meeting, 2010.

[6] Poli R, Kennedy J, Blackwell T. Particle swarm optimization. An overview Swarm Intelligence, 2007, 1(1):33-57

[7] Vapnik V. The Nature of Statistical Learning Theory. New York, Springer 1995

[8] Feijoo A E, Cidras J, Dornelas J L G. Wind Speed Simulation in Wind Farms for Steady-state Security Assessment of Electrical Power system [J]. IEEE Trans on Energy Conversion, 1999, 14(4): 1582-1588.

[9] Yu Haimiao, Zhou Haizhu, Pei Xiaomei. Environmental Value and Economic Analysis of Wind Power [J].Journal of Tongji University (Natural science), 2009, 37(5): 704-708.