OPTIMAL PLACEMENT OF SECTIONALIZING SWITCHES IN DISTRIBUTION NETWORK WITH PRESENCE OF RENEWABLE ENERGY RESOURCES

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ABSTRACT

This paper proposes a method to determine the location of sectionalizing switches in presence of stochastic renewable resources. Particle swarm optimization is used for placement of sectionalizing switches with considering an objective function. The proposed objective function is composed of two terms: minimizing of cost of sectionalizing switches and maximization of reliability benefit. Mono carlo simulation is used to reliability assessment. The performance of the proposed approach is assessed by a real distribution network.

INTRODUCTION

It has been estimated that most of the supply interruptions to customers are because of failures in the distribution networks[1]. The annual outage time of customers depends on the frequency and duration of interruptions. The frequency of interruptions can be reduced by improving the failure rates whereas the duration can be reduced by decreasing the restoration time. An effective way to reduce the restoration time is installation of sectionalizing switches. After a fault occurs, it is located and the faulted part is isolated using sectionalizing switches. Then load is restored as soon as possible from the main or alternative sources. The effectiveness of this process strongly depends on the number and location of sectionalizing switches [2]. One of the new changes in the distribution configurations is a growth in distributed generation (DG) [3]. One of the advantages that DGs can provide to the electric utilities and to customers is the possibility of improving the continuity of supply after an outage in the main feed line or in the primary substation. Sectionalizing switches play a key role in this reliability improvement and hence the selection of an adequate number and location of these devices is an important factor in presence DG. In the other hand, due to the widespread presence of renewable energy resources in distribution networks, the optimal location of sectionalizing switches will be affected. With consideration of stochastic nature of renewable energy resources and load variations, the location of sectionalizing switches affect on restoration process. In fault conditions, the location of sectionalizing switch will affect on the amount of restored load, so that with increasing restored zone, the amount of restored load will be increased (for example, in figure 1 for fault occurrence between bus-2 and bus-3, if sectionalizing switch-3 is opened, the supplied load will be more than state of

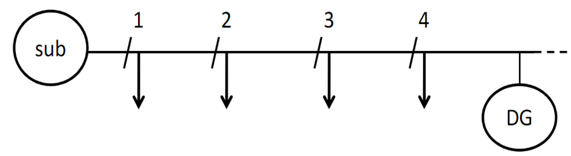

Figure 1: example feeder.

opening switch - 4); On the other hand, due to uncertainty nature of renewable sources production, grater restoration zone lead to increase the probability of not supplied load. In other words, the risk of load supply will increase (for example, in figure 1, for fault occurrence between bus-2 and bus-3, if sectionalizing switch-3 is opened, the risk of load supplying will be more than state of opening switch-4); And also, with increasing the restoration zone, the probability of fault occurrences in that zone will increase in proportional to the total fault occurrence in the network (for example, in figure.1, for fault occurrence between bus-2 and bus-3, if sectionalizing switch -3 is opened, the probability of fault occurrence will be more than state of opening switch- 4).

With consideration the above problem, in this paper a heuristic method is proposed to determine the location for sectionalizing switches with considering wind turbine (WT) generators. The objective function is considered minimizing of cost of sectionalizing switches and maximization of reliability benefit. Mono carlo simulation is used to reliability assessment.

PROPOSED METHOD

In this paper, an efficient methodology is proposed for finding the number and location of sectionalizing switches in distribution networks including WT resources. The proposed approach aims to optimize the location of sectionalizing switches for reliability improvement in the primary distribution network. Particle swarm Optimization (PSO) is used to determine location of sectionalizing switches.

The proposed approach model with two conflicting objectives:

—improving reliability of service;

—minimizing cost of sectionalizing switches.

The first objective can be formulated using various reliability indices. Annual expected energy not supplied (EENS) index is chosen to assess the service reliability. Monto carlo simulation is used to determine EENS. The second objective represents minimization of cost of sectionalizing switches.

Wind turbine modeling

Due to existing uncertainty in power generation more challenges exists behind distribution system reliability assessment. It is obvious that due to these uncertainties, reliability indices and other system performance indices have uncertainties. In this paper, the random generation of renewable DG is represented with a probabilistic approach, in which a probability distribution function is utilized to deal with DG output modeling. The power production probability distribution function is calculated based on probability distribution function of DG's primary resource. With consideration of distributed generation technical characteristic and renewable primary resource behavior, probability density function of power output is calculated. In this paper, wind speed probability distribution function is calculated for one year, and then probability distribution function of DG power production is calculated in accordance with wind speed probability distribution function.

Wind turbine power generation with respect to wind speed is illustrated in (1).

$$P_{WT}=\begin{cases}0 & w<w_{cin}\\ p_r.(A-Bw+cw^2) & w_{cin}<w<w_r\\ p_r & w_r<w<w_{co}\\ 0 & w>w_{co}\end{cases} \quad (1)$$

Where P_{WT} is power generation of wind turbine, P_r is nominal power production of wind turbine, w is wind speed, w_{cin} is cut-in wind speed, w_r is nominal wind speed, w_{co} is cut-out wind speed. A, B and C coefficients are calculated according to wind turbine technical characteristics [4].

Load modeling

Access to load data is one of the most important and difficult steps in planning and operation of distribution systems. Load in distribution networks can vary with time over a wide range and can be stochastic in nature. Load survey and load allocation mathematical techniques are used for estimation of load at unmetered points of load. A probabilistic representation of load is proposed in this paper for sectionalizing switch placement procedure. This approach considers various load estimation scenarios with different occurrence probability. Load duration curve (LDC) is approximated with piecewise curve for DG placement as shown in figure 2. By increasing the numbers of segments in LDC, results are more accurate but time consuming and vice versa [5].

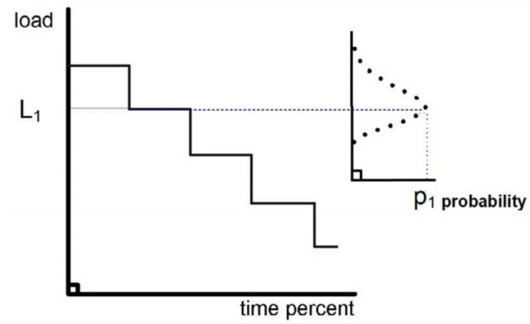

Figure 2: Load duration curve as piecewise with uncertainty

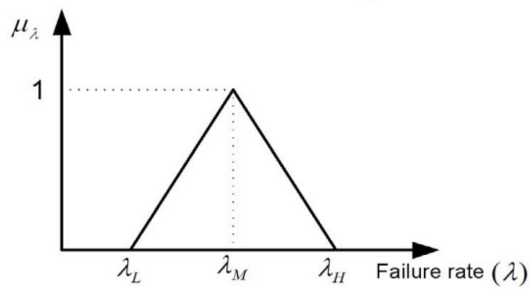

Figure 3: fuzzy representation of failure rate.

Failure rate and time repair modeling

Failure rate of power distribution system components vary with many different factors. Overhead distribution lines are highly affected by weather because the lines are exposed to the atmosphere. Wind, lightening, ice, tornadoes and other weather related factors could cause line failures. High tree density near a line or negligence of tree trimming can also cause frequent interruptions. Therefore failure rate prediction exposed to different uncertainties due to these factors. For description of inherent uncertainty in failure rate of feeders and other components of distribution system, fuzzy number is used as shown in figure 3.

Reliability formulation

Reliability improvement and reducing expected energy not supplied (EENS) is one of the objective functions that considered in this paper for sectionalizing switch placement. Distribution system reliability assessment procedures with consideration of uncertain failure rate and repair time and in presence of renewable distributed generation will be discussed in the following section.

Distribution system Reliability Assessment in Presence of Wind Turbines:

Presence of DGs in power distribution system can improve reliability as well as sectionalising switch can. Based on the restoration stages described earlier, EENS can be calculated for various contingencies using (2).

$$\tilde{EENS}=\sum_{i=1}^{N_b}\tilde{\lambda}_i.L_i.(\sum_{j\in island}LP_j.r_{switching}+\sum_{J\notin island}LP_j.\tilde{r}_{repair}) \quad (2)$$

Where $EE\tilde{N}S$ is the fuzzy expected energy not supplied, N_b 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 $\tilde{r}_{repair}$ is the fuzzy presentation of fault repair time. Due to probabilistic modelling of DG generation and load, Monte Carlo simulation is used to calculate energy not supplied. In this problem we supposed that one dispatchable DG unit such as synchronous generator will be located near the renewable distributed generation units for guarantee their synchronism. This unit is considered only for island forming. Their capacities are not considered for load supplying and objective function improvement. Although this calculation could be done with consideration of synchronous generations and renewable DG units, simultaneously.

Objective function

The objective function is formulated as follow.

$$\min Z = C_{Sec} + C_{ENS} \qquad (3)$$

Where C_{Sec} is represented sectionlizer cost and C_{ENS} is denoted cost of energy not supplied, and determined as follows:

$$C_{Sec} = N \times SSC \qquad (4)$$

$$C_{ENS} = \lambda_{ENS} \times ENS \qquad (5)$$

Where N is the number of sectionalizing switch, SSC is investment cost of each switch, λ_{ENS} and is wholesale market price.

CASE STUDY

The proposed method is tested on 20-kV actual radial distribution network from Eastern-Azarbayjan province in North West of Iran. Figure 4 depicts the geographical view of this overhead distribution network. This system has 53 sections, total length of 52.188 km, and 25 load points. The average load and power factor at each load point are 100 kW and 0.9. All sections in the system are overhead lines with $r(\Omega/km) = 0.1702$, $x(\Omega/km) = 0.3062$, $I_{\max}(A) = 280$. The maximum allowable voltage drop is 5%. This network is responsible for supplying the electrical demand of important loads, most of them are industrial. Because of the geographical limitations, connection with other distribution feeders by means of tie lines is not possible. Thus, in case of fault in the feeder, interrupted load can be restored only by the main supply. Eastern-Azarbayjan province is one of the industrial regions. Therefore, reliability improvement in this region is very important. One of the ways for reliability improvement in this feeder is use of generation sources installed at some of the industrial units as backup supply during outages in the feeder.

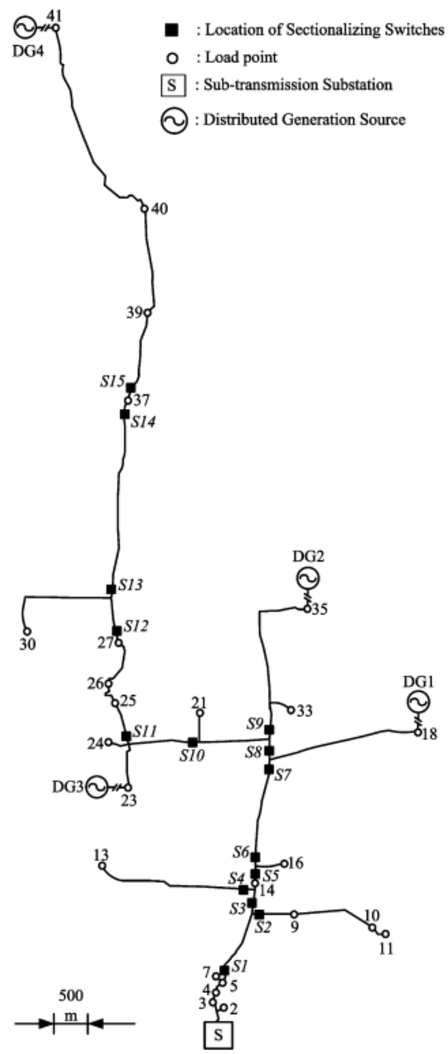

Figure 4: Geographical view of the real overhead distribution network.

Annual Load duration curve is divided into four level (figure 6). Three scenario with 7.5, 8, 8.5 peak demand and probability of 0.2, 0.6 and 0.4 is considerded.for simplicity, load have been equally divided among load point.

Table 1.repaire time and failure rate

Repair time (hour)	Failure rate(failure/year.km)
(1,1.5,2)	(0.01,0.07,0.18)

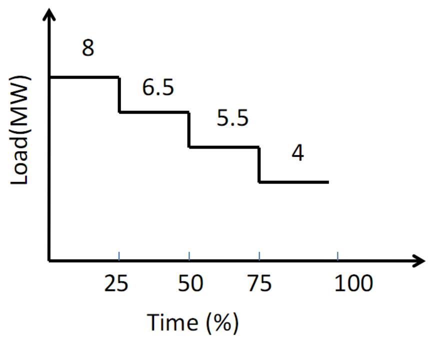

Figure 5. Annual load duration curve.

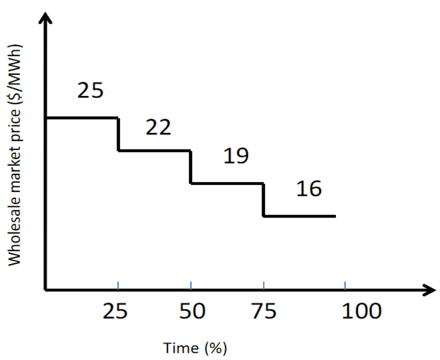

Figure 6: Wholesale energy prices.

In this case study we utilized wind turbines as distributed generations. Wind speed information has been obtained from real data that introduced by [6] for a specific area in Iran. Wind turbine characteristic is defined as follow.

$$P_{WT}=\begin{cases}0 & w<4\\ p_r.(0.032-0.077w+0.01745w^2) & 4<w<10\\ p_r & 10<w<22\\ 0 & w>22\end{cases} \quad (6)$$

p_r is considered 1 MVA andInvestment cost of switches is considered 2000 dollars.

Maximum number of sectionalizing switch is considered 5. Without consideration of DGs and sectionalizing switch, the value of EENS is 21230 kWh/year. After placement of switches without considering of any DG, location of switches is determined S7 and S10, and the value of EENS is 16536 kWh/year.

With considering DG1, DG2, DG3 and DG4 with characteristic equal to (6), and using the proposed method, the location of switches is determined as S5, S7, S8, S10, and S11. With considering DGs, the EENS is reduced to 8422 kWh/year, which shows 49.06% improvement. Based on the result, EENS improves significantly after placement of switches. In other study, two DG sources (DG2 and DG4) are considered in the system and other DGs are omitted. Without considering the value of EENS is 19362 kWh/year. With presence of DG2 and DG4, the location of switches is determined as S9 and S7. The EENS reduced to 17922 kWh/year.

CONCLUSION

This paper proposes a method to determine the location of sectionalising switches in presence of stochastic renewable energy resources. Particle swarm optimization is used to determine the location of switches according to proposed objective function. Objective function is composed of two objectives: minimizing of cost of sectionalizing switches and maximization of reliability benefit. Mono carlo simulation is used to reliability assessment. The proposed method has been applied to an actual distribution network. Study result shows improvement in reliability with considering DGs and sectionalizing switches. Also placement of sectionalising switches is depended on the location of DGs.

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