RELIABILITY IMPROVEMENT ASSIGNMENT TO DISTRIBUTED GENERATION IN DISTRIBUTION NETWORK

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ABSTRACT

The improvement of reliability is one of the main benefits of distributed generation(DG) in the distribution network. It is important for a distribution company (DisCo) to specify which DG is more beneficial for reliability improvement. In general the participation of each DG in reliability improvement might be different. So, in this paper a method is proposed to reliability improvement allocation to DGs in the distribution network. The proposed method determines the participation of each DG in the reliability improvement index. The effectiveness of this method is verified through numerical results on a sample 33-bus system.

INTRODUCTION

With the increasing pressure of environmental issues and desire to lower-carbon economy, the smart grid development is an inevitable trend for many countries [1-3]. As a very important part of the smart grid, distributed generations (DGs) most of which are based on renewable energy are widely introduced to the present power distribution system [4]. DG can provide benefits to the distribution companies (DisCos) such as loss reduction, emission reduction, reliability improvement, voltage profile improvement, reducing the risk of overloading the distribution feeders, reducing the construction period and reducing the cost of energy purchased from power market and investments deferral [5].

The improvements in the reliability of the distribution network have been pointed out as one of the most important benefits [6-7]. In the other hand, increasing attention is currently being paid to microgrids as an alternative or complement to large centralized generation plants, especially to their potential role in increasing power system reliability [8]. Microgrid can operate in two different modes: interconnected or emergency [9]. In an interconnected mode, the microgrid is connected to the distribution network, importing or exporting electricity and/or ancillary services [9]. When in emergency mode, the microgrid operates isolated from the distribution network and uses local resources, changing from power control to frequency control and, if necessary, shedding load. In emergency mode, DGs located in the island will improve reliability. The contribution of each DG in reliability improvement might be different. It is related to their capacity and ability to frequency control in formed island.

Several studies and papers discussing the impact of DG on reliability of distribution networks have been published [10-11]. In general, those publications deal with the impact of interconnected DGs on reliability improvement and do not explore the contribution of each DG in reliability improvement. While in order to have a fair incentive for reliability improvement, distribution company (DisCo) should specify which DG units are more beneficial to them and determine each DG contribution in reliability improvement.

In this paper, we intend to determine the contribution of each DG unit in reliability improvement in emergency mode by proposing a method for reliability improvement allocation between various DG units which are connected to the distribution network.

PROPOSED METHOD

As discussed in previous section, in this paper, a method is represented to allocation of reliability improvement to the DG units which are located at a microgrid.

To investigate the proposed method, consider the sample network shown in figure (1).

In the case of a fault occurrence in the network, DGs can supply a part of the curtailed load. As an example, consider a fault occurring on the line between buses 5 and 6. In this case, the network is divided into 2 areas. Area-2 can be operated as microgrid which DGs are installed in have a positive impact on reliability index.

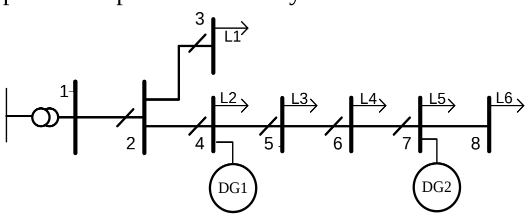

Figure 1: sample network.

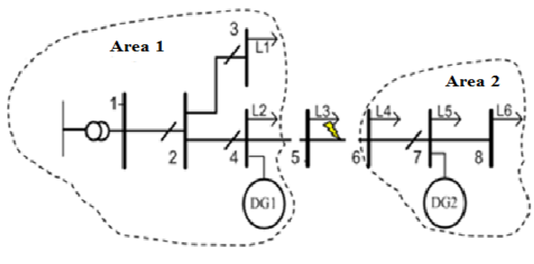

Figure 2: network configuration after fault occurrence.

In the case of presence of several DG in microgrid, the contribution of each DG in reliability index improvement might be different. It is related to their capacity and ability to frequency control in formed island.

So, in this paper a method is proposed to determine the contribution of each DG in reliability index improvement. The proposed method is based on the flowchart shown in Figure (3). It should be noted that, in proposed method energy not supplied (ENS) and interruption cost indices are used to evaluation of DGs impact on network reliability.

The major steps of the proposed algorithm are:

Step 1: determination of ENS and interruption cost assuming absence of DGs in island: in this step the ENS and interruption cost is determined as follows:

$$TD_1 = \sum_{i\in B} CDF_i(D)\times L_i \qquad (1)$$

$$ENS_1 = \left[\sum_{b=1}^{N_b} \gamma_b \times L_b \times \left(\sum_{res=1}^{Nres} p_{res} t_{res} + \sum_{rep=1}^{Nrep} p_{rep} t_{rep}\right)\right] \qquad (2)$$

Where $CDF_i(D)$ is customer damage cost which is located at bus-i ($/MW). CDF is related to the duration of fault. L_i is customer load capacity(MW), N_b is the number of branches in network, γ_b is branches failure rate(f/km.year), L_b is branch length (km), N_{rep} is number of nodes isolated during fault location, P_{res} is load s which are restored during fault, P_{rep} is loads are not restored during fault, t_{res} is duration of the fault location and switching time, and t_{rep} is duration of the fault repair [3].

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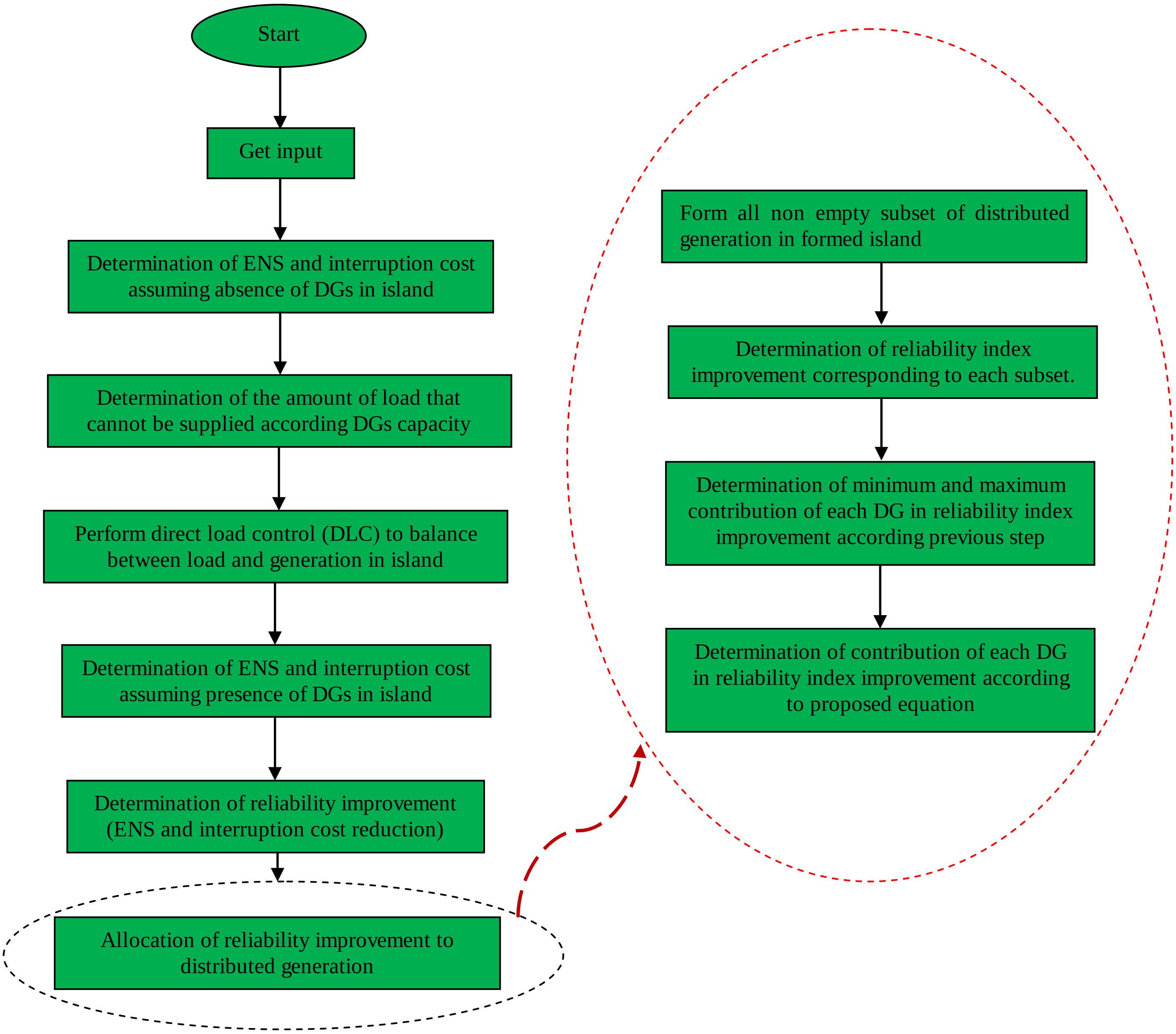

Figure3: reliability improvement allocation algorithm

Step 2: Determination of the amount of load that cannot be supplied according DGs capacity and perform direct load control (DLC) to balance between load and generation in island. The amount of load that cannot be supplied is determined as follows:

$$LNS = L_{total} - P_{DG}^{total} \quad (3)$$

It is assumed that the DLC program is used to balance between load and generation formed island.

Step 3: Determination of ENS and interruption cost assuming the presence of DGs in the island. In this step with assuming the presence of DGs in formed island customer damage cost (TD_2) and ENS cost (ENS_2) is calculated.

Step 4: Determination of reliability improvement (ENS and interruption cost reduction). The reliability index improvement is determined as follows:

$$ICR = TD_1 - TD_2 \quad (4)$$

$$ERI = ENS_1 - ENS_2 \quad (5)$$

Step 5: Allocation of reliability improvement to distributed generation. In this step the contribution of each DG in reliability index improvement is determined as follows:

1- Form all non empty subset of distributed generation in formed island. As an example, with assuming the presence of three DGs ($\{1,2,3\}$) in island, following subset can be formed:

$\{1\}$	$\{2\}$	$\{3\}$	$\{1,2\}$	$\{1,3\}$	$\{2,3\}$	$\{1,2,3\}$

2- Determination of reliability index improvement corresponding to each subset.in this step CDF and ENS improvement corresponding to each subset is determined as follows:

Subset (s)	CDF improvement ($v_1(s)$)	ENS improvement ($v_2(s)$)
$\{1\}$	ICR_1	ERI_1
$\{2\}$	ICR_2	ERI_2
$\{3\}$	ICR_3	ERI_3
$\{1,2\}$	ICR_4	ERI_4
$\{1,3\}$	ICR_5	ERI_5
$\{2,3\}$	ICR_6	ERI_6
$\{1,2,3\}$	ICR_7	ERI_7

3- Determination of minimum and maximum contribution of each DG in reliability index improvement as follows:

$$W_i = v(\{1,2,...,N\}) - v(\{1,2,...,N\} - \{i\}) \quad (6)$$

$$w_i = \max(v(z_i) - \sum_{\substack{j \in z \\ j \neq i}} W_j) \quad (7)$$

Where W_i and w_i are the minimum and maximum contribution of each DG in reliability index improvement.

4- Determination of contribution of each DG in reliability index improvement according to the following equation:

$$ICR_{DGi} = \beta^{icr} w_i^{icr} + (1-\beta^{icr})W_i^{icr} \quad (8)$$

$$ERI_{DGi} = \beta^{eri} w_i^{eri} + (1-\beta^{eri})W_i^{eri} \quad (9)$$

Where

$$\sum_i ICR_{DGi} = v_1(\{1,2,...,N\}) \quad (10)$$

$$\sum_i ERI_{DGi} = v_2(\{1,2,...,N\}) \quad (11)$$

CASE STUDY

The proposed method is tested using the 33-bus distribution system showing in figure (4) [12]. The line data are provided in the [12]. Load data are provided in table I. It is assumed that there are sectionalizing switches at buses (2), (4) , (5), (8) (13), (19), (23), (26), (30).customer damage cost is represented in table (2). It is assumed that two DGs with the capacity of 500 kW and 200 kW are located on the buses 30 and 18 respectively. DG on bus-30 is assumed to have the ability of frequency control.

In the case of fault occurrence in line-6, an area including buses 8-18 and 26-33, can be operated as an island. In this island there is two DGs that can supply island's loads. So, the reliability index will be improved. Table (3) shows the contribution of each DG in reliability index improvement.

As can be seen, the impact of DG-30 on customer damage cost reduction is greater than the other one. Because the capacity of DG-30 is greater as well as just it has the ability of frequency control.

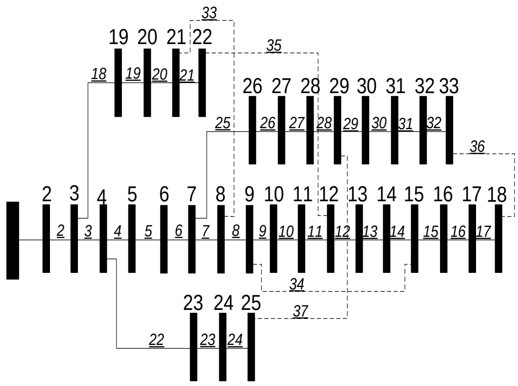

Figure 4: sample 33-bus system

Table I: Load data

Bus. No	P (kW)	Q (kW)	Bus. No	P (kW)	Q (kW)

1	0	0	18	90	40
2	100	60	19	90	40
3	90	40	20	90	40
4	120	80	21	90	40
5	60	30	22	90	40
6	60	20	23	90	50
7	200	100	24	420	200
8	200	100	25	420	200
9	60	20	26	60	25
10	60	20	27	60	25
11	45	30	28	60	20
12	60	35	29	120	70
13	60	35	30	200	600
14	120	80	31	150	70
15	60	10	32	210	100
16	60	20	33	60	40
17	60	20			

Table II: customer damage cost

Customer type	Interruption duration (min) and cost ($/kW)			
	30 min	60 min	120 min	150 min
Industrial	4.905	13.59	17.72	19.05
Commercial	3.696	13.53	18.948	23.544
Residential	0.35	3.56	5.48	8.12

Table III:DG's size and location

DG. bus	ICR($)	EIR(kW)
18	1452	100
30	7995	600

Since DG-18 has not the ability of frequency control, it can not be operated separately,while DG-30 can.
It is also observed that the effect of DG-30 on ENS reduction is greater than DG-18 too. This happens because of reasons including the capacity of DG-30 and it's ability in frequency control as discussed for ICR improvement.
It should be noted, if both DGs have frequency control capability, the contribution of each of them in ENS reduction will be equal to their capacity.

CONCLUTION

On of the main benefit of DGs in the distribution network is their effect on reliability improvement. Many of the studies regarding DG investigate the problem of determination of reliability improvement in the distribution network. But it is important for a DisCo to specify which DG is more beneficial for reliability improvement. In general the participation of each DG in reliability improvement might be different. So, this paper proposes a method to allocation of reliability improvement to DGs in the distribution network. The proposed method determines the participation of each DG in the reliability improvement index. From the numerical result, it has been derived that the contribution DGs which have the capability of frequency control is greater than another one.

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