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Improvement of Distribution System Reliability by Changing the Feeder Position

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Abstract: The electricity providing with good quality has been always the most important aim of distribution network operators. In recent years the importance of this issue is increasing due to the competitive electricity market in new deregulated electric utility. In this paper, an applicable and practical method is presented to improve the reliability indexes in design and operation of system. This method is based on supply point changing in a distribution system and investigating the effects on load and system reliability indexes. Obviously, doing such a thing has some cost (if it be possible) which varies for each changing. Then, in another step, the interruption cost is estimated along the other indexes for each new structure. Finally, by comparing the obtained results, the best place for system supply can be found from reliability and economical point of view. In the end, a sample system is stimulated by using ETAP software and the obtained results are evaluated.

Key words: Reliability Assessment, Feeder Place Changing, Distribution System.

INTRODUCTION

The importance of accessing the acceptable reliability level, power quality and safety is increasing with the growing dependence of modern societies to electrical energy. The power cut is inevitable due to the imbalance which exists in different parts of system. It can be decreased to some extent by increasing the system reliability but it can not be completely removed. Nowadays creating the balance between the reliability improvement cost and the overall electricity cost for consumers has become the key purpose of modern power systems. In one hand, by increasing the reliability level, the total cost for customers will be increased. On the other hand, by decreasing the total charge the system will have the subtle reliability. To overcome this inconvenience the best way is when the total sum of costs is minimized. In (Billinton, 1998), an effective method based on system reliability is presented. In this method, a system is divided into some simple subsystems. The reliability index for each subsystem is calculated then by combining the obtained values, the total index can be calculated.

In (Xie, 2003), a method based on the shortest path is proposed to estimate the system reliability. In this method, the reliability index can be computed by finding the shortest path (based on graph theory) from one node to supply and between two knots. In (Billinton, 1999), a method is given which can assess the protective equipment type in predetermined situations on a feeder distribution. This method is based on minimizing the reliability index like SAIFI.

In (Billinton, 2007), a technique has been evaluated to study the effect of automation on reliability index. In this technique which is based on event-tree, an atomized system is chosen and by applying different ways and comparing obtained results, the value of automation is assessed. It is complex to directly estimate the reliability due to different effective parameters and mass information in power system. One of the efficient ways is evaluating the interruption cost for customers. In (Iyer, 2005), a new method is introduced to estimate the cost for customers and then is compared with the classic methods. In this method by analysis of load data, it has been considered that the estimated value of cost can be so close to real value.

In this paper, an applicable method is presented to improve the reliability indices in distribution systems. In this method the effect of changing the feeder position on reliability of load point and system is investigated. Then in another step, the outage cost is estimated for customers in each new structure. Finally, with comparing the obtained results, a place is found that it is the best place for supplying the system from point of reliability view. In the end, the effectiveness of proposed algorithm is demonstrated by applying ETAP software to a sample system.

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Reliability Assessment in Distribution System:

Regarding the usual (common) structure of distribution which has been operated in radial, the reliability assessment is done by series combination of elements from the supply point to the specific load.

In the classic reliability assessment, three parameters for each load are defined which are as follow:

λ: failure rate of the component.

r: mean repair time of the component.

U: unavailability of the component.

Although the reliability of each load and customer can be estimated by having above parameters, some other indices should be defined to analyze the reliability of the system. The common indexes which are known as system reliability indices are as follows:

System Average Interruption Frequency Index (SAIFI):

$$SAIFI = \frac{\sum \lambda_i N_i}{N} \tag{1}$$

System Average Interruption Frequency Index (SAIFI):

$$SAIDI = \frac{\sum U_i N_i}{N} \tag{2}$$

Customer Average Interruption Frequency Index (CAIFI):

$$CAIFI = \frac{\sum \lambda_i N_i}{N_c} \tag{3}$$

Customer Average Interruption Duration Index (CAIDI):

$$CAIDI = \frac{\sum U_i N_i}{\sum \lambda_i N_i} \tag{4}$$

Where in these equations N, N_c are the number of customers and number of customers affected respectively.

The above parameters are based on the customer numbers but in the energy part of system the following definitions can be written as:

Energy Not Supplied (ENS):

$$ENS = \sum U_i . L_i \tag{5}$$

Average Energy Not Supplied (AENS):

$$AENS = \frac{ENS}{N} \tag{6}$$

Which U and L are unavailability and average consume power of each customer respectively. According to above definitions, all of indices are based on the three basic parameters λ, r and U. So, the most important issue in reliability assessment is to estimate these parameters as precise as possible.

Estimation of Interruption Cost for Costumers:

Figure 1 shows the configuration of proposed UPQC, which additionally has a DC/DC converter and super-capacitors for compensating the voltage interruption. The energy in the DC link charges the super-capacitors through the bi-directional DC/DC converter when the system is in normal operation.

The energy in the super-capacitors is released to the DC link through the bi-directional DC/DC converter when the voltage interruption occurs. Today, in competitive electricity markets, the purpose of distribution companies is to provide energy for customers with high reliability along with minimum cost. Therefore, using

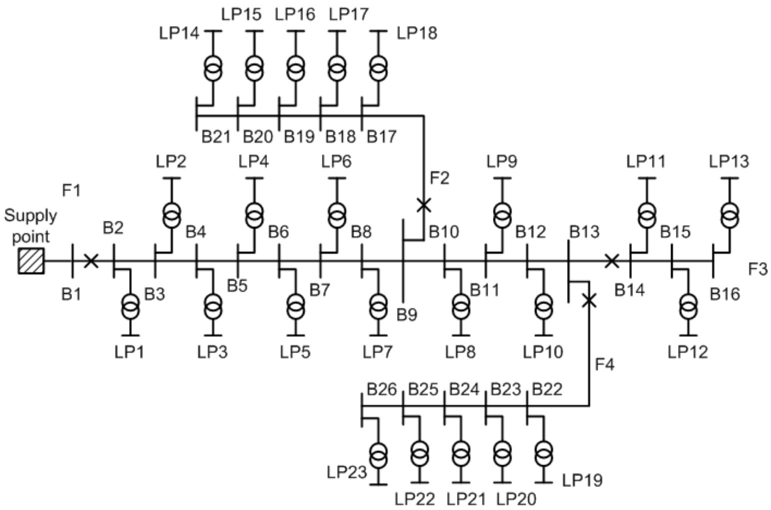

Fig. 1: 26-Buses distribution system.

only common indices, as described in section II of this paper, is not enough to succeed in their goals. Also, in developed countries the providing companies are obliged to pay interruption cost to customers is another reason for the importance of using economical indices along with technical ones. The most important index in estimating interruption cost is:

$$ECOST_k = L_k . d_k . LPCDF_k \qquad (7)$$

where:

L_k: Average load (kw) at hour (k).

d_k : Outage duration at hour (k).

LPCDF : Load point cutomer damage function.

The expected interruption cost which is calculated by Equ. 7. Furthermore, other effective parameters in ECOST are the costumer type. Because the energy value and interruption cost vary for different customers like in industrial, agricultural, official and residential parts. The curtailed cost versus time for different costumer is presented in Table 1. The results of above table have been obtained experimentally (Wang, 2007).

Table 1: Sector interruption cost estimates expressed in kw of annuals peak demand.

	Interruption duration				
Interruption cost	1 min	20 min	60 min	240 min	480 min
Large Load	1.005	1.508	2.225	3.968	8.24
Industrial	1.625	3.868	9.085	25.16	55.81
Commercial	0.381	2.969	8.552	31.32	83.01
Agricultural	0.06	0.343	0.649	2.064	4.12
Residential	0.001	0.093	0.482	4.914	15.69
Govt. & inst	0.044	0.369	1.492	6.558	26.04
Official	4.778	9.878	21.06	68.83	119.2

The Effect of Changing the Supply Point on the Reliability Indexes:

The curtailed cost for specific system reliability can be determined by using common reliability indexes which were presented in two previous parts. The reliability assessment depends on the system structure, the protective equipment type, situation and load type and values. So, among different methods to improve the reliability level, the system structure variation and distributed generation can be mentioned.

One of the main characteristics of distribution system is radial operation. So, the system is fed from just one point that choosing this place occurs in design part and some indexes such as technical, economical and even geographical parameters are also considered. Because the supply point is unique, changing of that is so effective in network topology and as a result in parameters like power system losses.

In this paper, by changing the feeder supply point in available buses, the reliability for each structure has been estimated. It is obvious that regarding the feeder type, the load type and combination of existent loads, placing the feeder supply point in a specific bus can lead to the highest reliability level. Therefore, this bus is the desirable point to connect the distribution system to another network. One should pay attention that supply point changing (if it be possible) has some cost which varies for different buses. Therefore, the most suitable bus can be chosen by estimating the curtailed cost and comparing with cost of creating the considered structure. Needless to say, the best bus is where the profit of decreasing the interruption damage cost for customers and supplying point changing cost (SPCC) is maximized. Hence, the objective function can be defined as follows:

$$\max \quad profit = ECOST_0 - (ECOST_i + SPCC_i) \tag{8}$$

Where:
$ECOST_0$: interruption damage cost in first place
$ECOST_i$: interruption damage cost in bus number i
$SPCC_i$: Supply point changing cost from the first place to bus number i

RESULTS AND DISCUSSION

To evaluate the presented method, a system like Fig. 1 is considered which includes 26 buses, 23 branches, load point and three feeders. Diversity of loads and size of this system are similar to a real network, so it was selected to evaluate in this paper. Relevant data about this system with its customers is given in (Billinton, 1998) and (Billinton, 1991). According to Fig.1, all of the branches and feeders are protected by fuses and circuit breakers respectively with the 100 percent reliability level. Two following parts are mainly discussing the effect of supply point changing on reliability indexes by using ETAP software. To verify the method, the paper is explaining two scenarios in details.

A. Choosing the Best Supply Point Regarding Reliability Indexes:

Here, first of all the reliability indexes for the current supply point (bus No.1) are evaluated. Then, by changing the supply point from one bus to another, all indices for the new structure are calculated. It is supposed that every change from one bus to another is possible. The obtained values of indexes for different buses are listed in Table.2. Also, in fig.2, the variations of EENS energy-based index for each structure are included as well.

Table 2: Estimation of reliability indices by supply point changing in the system (scenario1).

Bus no.	SAIFI	SAIDI	CAIDI	ASUI	AENS
1	0.9063	7.4042	8.17	0.00085	0.046
2	0.8425	7.0887	8.414	0.00081	0.0452
3	0.5801	5.785	9.973	0.00066	0.0371
4	0.5239	5.5081	10.513	0.00063	0.0353
5	0.5372	5.5744	10.378	0.00064	0.0338
6	0.519	5.4847	10.568	0.00063	0.0326
7	0.4995	5.3882	10.787	0.00062	0.0318
8	0.4829	5.3063	10.988	0.00061	0.0311
9	0.422	5.0054	11.86	0.00057	0.0297
10	0.5499	5.6389	10.255	0.00064	0.0326
11	0.5565	5.6716	10.192	0.00065	0.034
12	0.5574	5.6763	10.183	0.00065	0.0364
13	0.6535	6.1521	9.414	0.0007	0.038
14	0.7608	6.6835	8.784	0.00076	0.0441
15	0.8869	7.3074	8.239	0.00083	0.0466
16	1.0308	8.0194	7.78	0.00092	0.0492
17	0.7385	6.5727	8.9	0.00075	0.0419
18	0.8468	7.1085	8.395	0.00081	0.0438
19	0.9876	7.8055	7.903	0.00089	0.0461
20	1.0445	8.0867	7.742	0.00092	0.0485
21	1.1025	8.3733	7.595	0.00096	0.0512
22	0.8308	7.0298	8.461	0.0008	0.0419
23	0.962	7.6789	7.982	0.00088	0.0435
24	1.0143	7.9371	7.826	0.00091	0.046
25	1.0664	8.1947	7.685	0.00094	0.0487
26	1.1238	8.4788	7.545	0.00097	0.0515

According to obtained results from Table.2 and Fig.2, it can be understood that the best places in case of reliability and energy-based indices are buses numbers 7, 8 and 9.

As mentioned before, the supply point changing (if be possible) has cost and to justify the method, the ECOST index is considered for all the changing in buses and the results are presented in Fig.3. After that with Equ.8, the maximum profit is calculated just for buses in which the reliability level has been improved compared with the first bus. In this network for example, changing supply point to the buses number 14, 15, 16, 20, 21 and 26 is not consider. By supposing equal changing cost for all buses in this network, the maximum profit is obtained when the system is fed from bus number 9. Choosing this point depends directly on load type, location and curtailed cost.

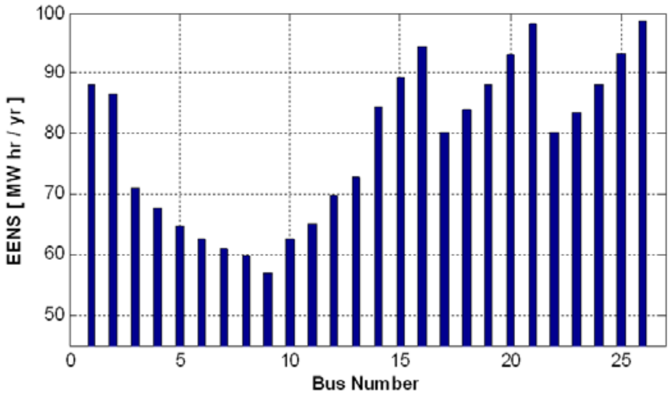

Fig. 2: Variation of EENS for different cases of system.

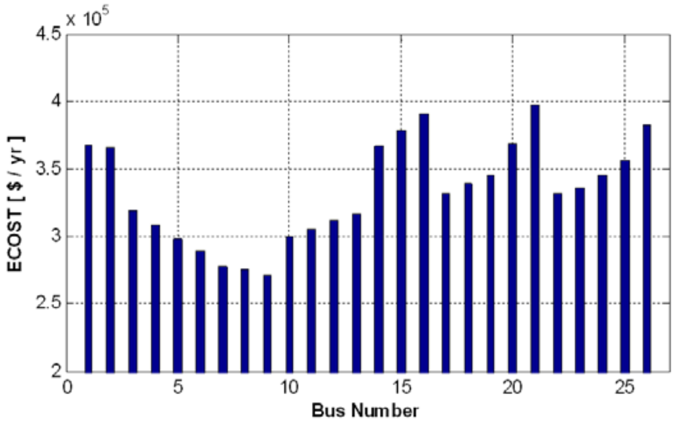

Fig. 3: Estimation of ECOST for different cases of network in scenario 1.

B. the Effect of Load Variation on Choosing the Best Place for Supply Point:

Load variations including load increase, adding a new customer and customer variation type in distribution system is inevitable. According to reliability indexes definitions, every load variation affects the value of these parameters and therefore the best supply point.

To analyze this effect, it is assumed that in previous system commercial load in load points 8 and 9 has increased about 25 percent (like building a new commercial center) in five years for example. In this case like pervious scenario, the reliability indexes for each supply point changing to all buses are calculated and the results are listed in Table.3. By comparing the results with previous ones, it shows that (as expected) the load variations have only affected the energy-based indices and had no effect on other indexes.

As a result, like previous scenario, buses number 7, 8 and 9 are chosen as best places for supply point. Also by considering ECOST index in Fig.4, these buses are candidates to analysis by Equ.8 for choosing the best position for supply point. So, in this case the changing cost of supply point to mentioned buses of system is the only factor that determines the best bus.

Table 3: Estimation of reliability indices by supply point changing in system (scenario2).

Bus no.	SAIFI	SAIDI	CAIDI	ASUI	AENS
1	0.9063	7.4042	8.17	0.00085	0.0471
2	0.6595	6.1767	9.366	0.00071	0.0401
3	0.5801	5.785	9.973	0.00066	0.038
4	0.5239	5.5081	10.513	0.00063	0.0361
5	0.5372	5.5744	10.378	0.00064	0.0346
6	0.519	5.4847	10.568	0.00063	0.0334
7	0.4995	5.3882	10.787	0.00062	0.0324
8	0.4829	5.3063	10.988	0.00061	0.0318
9	0.422	5.0054	11.86	0.00057	0.0306
10	0.5499	5.6389	10.255	0.00064	0.0335
11	0.5565	5.6716	10.192	0.00065	0.035
12	0.5574	5.6763	10.183	0.00065	0.0374
13	0.6535	6.1521	9.414	0.0007	0.0391
14	0.7608	6.6835	8.784	0.00076	0.0452
15	0.8869	7.3074	8.239	0.00083	0.0478
16	1.0308	8.0194	7.78	0.00092	0.0504
17	0.8278	7.0161	8.476	0.0008	0.0467
18	0.9525	7.6337	8.015	0.00087	0.0489
19	0.9177	7.4589	8.128	0.00085	0.0492
20	0.9706	7.7203	7.954	0.00088	0.0508
21	1.0245	7.9871	7.796	0.00091	0.0527
22	0.9328	7.5338	8.076	0.00086	0.0464
23	0.9886	7.8097	7.9	0.00089	0.0475
24	1.0404	8.0659	7.753	0.00092	0.0488
25	1.0921	8.3215	7.62	0.00095	0.0505
26	1.1456	8.5859	7.495	0.00098	0.0524

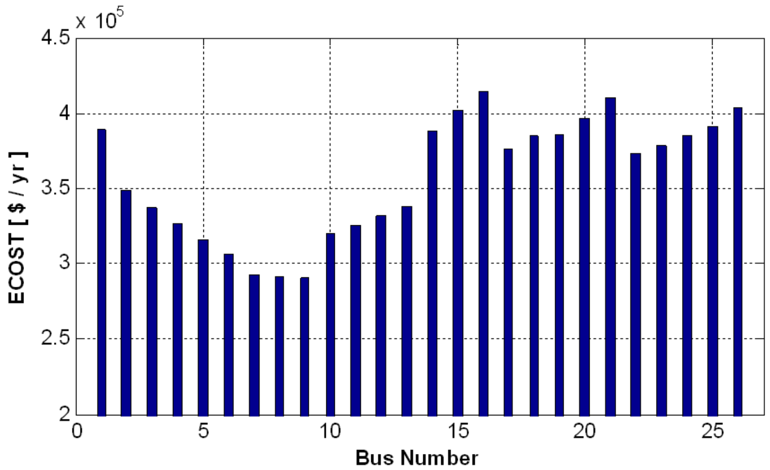

Fig. 4: Estimation of ECOST for different cases of network in scenario 2.

Conclusion:

In this paper, a new method is presented to improve the reliability indices in distribution systems. This method is based on changing supply point to each bus (if be possible) in network. For each new position, all the reliability indexes are calculated and evaluated. Then, by comparing the results, the suitable points from this point of view are chosen. In another step, the ECOST index is calculated for these points and by considering the supply point changing cost, the best point is chosen economical-wise. Obviously, the chosen point is technically best place as well. The connecting place of distribution system to above network is unique that is the main reason why changing this place is so effective on reliability level. Furthermore, the best point for system supply is economically desirable so that it can be so beneficial for distributed companies in addition to compensate for changing cost. Moreover, it can be pointed out that load type and load point in system are the effective factors in presented results. As verified in the paper, load increasing or adding new points of load can change the optimal point of system supply. So this method would be useful for planning as well as operating distribution network companies.

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