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A Systematic arranging method for reclose-fuse coordination in distribution system in appearance of DG

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Abstract: In this paper, a new and practical method is presented to investigate the effect of distributed generation (DG) on reclose-fuse coordination. The main idea is evaluation of reclose-fuse coordination status in appearance of DG and also fault occurrence in each buses of the test system, and then sorting cases in coordination-hold or coordination-lost groups. After that, two steps are driven. The first one is finding the best location of DG, and the other is adjusting (changing) the reclose and (or) fuses setting in order to improve the overall coordination status. Faults occurrence probabilities are not equal and decreased as distance from substation increased. This proposed method has been implemented on the IEEE 37-node feeder, by writing the script in MATLAB and the results are presented.

Key words: Distributed generation (DG); Protection coordination; Fuse-reclose; Probabilistic fault

1. Introduction

The main protection devices in electric distribution systems (EDSs) are reclose fuses and circuit breakers (CBs). Reclose is located at the beginning of main feeders and protects EDSs from transient or temporary faults. While fuses are located at the head of (sub) laterals to protect EDSs from permanent faults. Recluse's slow characteristic also acts as a back-up of fuses (Gers and Holmes 2004; Anderson, 1999).

Protection coordination in EDSs means preserving the planned order of operation of protection device that is operation of (fast characteristic of) reclose, fuses and (slow characteristic of) reclose respectively.

Changing the operating point of EDSs due to Appearance of DGs can disturb this coordination. This situation deteriorates when the unplanned corporation of DGs in fault current increases (CIGRÉ, 1999).

Several approaches for coordination restoration in appearance of DGs are proposed in the literature. For example in (Brahma and Girgis, 2002), Girgis and Brahma proposed a solution based on replacing relays and recloses in the distribution network by microprocessor-based device. Farzanehrafat in (Farzanehrafat et al., 2008). Proposed a method to find the threshold value of the DG capacity, beyond which reclose-fuse coordination is lost. As another method, (Zeineldin and El-Saadany, 2010). Proposed a fault current limiter (FCL) to mitigate the impacts of DG on protection coordination.

Proposed method in this paper is based mainly on two steps. First, finding the best location for DGs to place in and second, changing the setting of protection devices so as to reduce probable mis-coordination. In these two steps, whatever faults occur nearer to substation, considered more important.

This paper is organized as follows. Section 2 introduces the selected system under study. Section 3 presents the detailed steps required to implement the proposed approach. The obtained results shown in section 4. Finally conclusion is drawn in section 5.

2. System under study

The IEEE 37-node 4.8 kV that is shown in fig. 1, selected as a test feeder in this paper. This feeder is an unbalanced distribution system and its data are presented in (Kersting, 2000). For better showing of DG's impacts, the regulator in the test system is removed. Modeling considerations of the test system are presented at the follows.

2.1. Protection Devices Design

A reclose is placed at the beginning of the main feeder and 20 fuses are installed at the beginning of lateral feeders. The reclose characteristic is expressed as in (1).

$$t(\mathrm{I}) = TD\left[\frac{A}{M^{p}-1}+B\right] \quad (1)$$

Where

t: operating time of reclose.
I: fault current pass through reclose.
TD: time dial setting.

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M: ratio of I/Ipick-up.
Ipick-up set point of relay current.
A, B, ρ constant coefficients

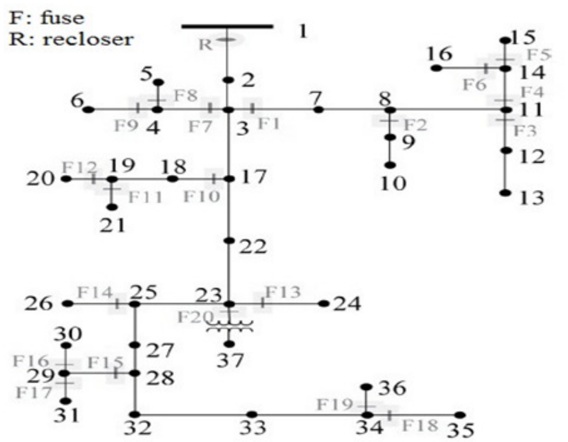

Fig. 1: 37-nodes test feeder

For prevention of reclose operation at overloaded condition, $I_{pick-up}$ is adjusted to (2).

$$I_{pick-up} = OLF \times I_{nom} \quad (2)$$

Where I_{nom} is maximum nominal current of the main feeder. Fuse characteristic is expressed as in (2) (Gers and Holmes 2004).

$$\log(t) = a.\log(I) + b \quad (1)$$

Where
t: operating time of fuse
I: fault current pass through fuse
a,b: constant coefficients

2.2. DG modeling

For calculation of load flow, DG can be modeled as PV or PQ nodes. In this paper, firstly, DG is modeled as a PV node and the required reactive power for holding of voltage magnitude at 1 p.u. is calculated. If the calculated reactive power was greater than DG's capacity, DG will act as a PQ node.

A. Load Model

Generally, loads are placed in three categories, constant impedance, constant voltage and constant current type. Type of loads in the test system, is presented in (Kersting, 2000). The used equations for modeling of the loads, is provided in Table. 1.

3. Proposed approaches

As a starting point, for adjustment of protection devices parameters, the load flow and short circuit analysis must be perform. After protection devices parameters adjustment, the proposed method can be start. This approach is described with following steps:

1. For any bus in the test system, a DG unit is considered to be installed in different penetrations, from 10 to 100 percent.
2. For any above state, a fault with its probability is considered to be located at each buses, except DG's bus and also bus 37. Probability of fault in any bus is considered to be increased, in proportion to its distance from main feeder.
3. At each of the mentioned states, corresponded protection devices and their orders of operation are determined.
4. The reclose and fuses operating time are calculated in any mentioned state and the results are compared with what was calculated in normal situation.
5. All states are categorized in two groups, labeled as coordination-hold and coordination-lost.
6. According to the above results, the best location for DG installation is selected and DG unit is installed to the selected bes.
7. After DG allocation, with consideration of fault probability, the protection devices settings be changed to Achieve minimum of miscoordination in protection system.

Table 1: Load models

Load type	Star	Delta
Constant PQ	$Il_i^{ph} = (\frac{S_i^{ph-n}}{V_i^{ph-n}})^*$	$Il_i^{ph} = (\frac{S_i^{ph-ph}}{V_i^{ph-ph}})^*$
Constant Z	$Z_i^{ph-n} = \frac{\lvert V_i^{ph-n}\rvert^2}{(S_i^{ph-n})^*}$ $Il_i^{ph-n} = (\frac{V_i^{ph-n}}{Z_i^{ph-n}})$	$Z_i^{ph-ph} = \frac{\lvert V_i^{ph-ph}\rvert^2}{(S_i^{ph-ph})^*}$ $Il_i^{ph-ph} = (\frac{V_i^{ph-ph}}{Z_i^{ph-ph}})$
Constant I	$Il_i^{ph-n} = \lvert Il_i^{ph-n}\rvert *$ $\angle(\delta_i^{ph-n} - \theta_i^{ph-n})$	$Il_i^{ph-ph} = \lvert Il_i^{ph-ph}\rvert *$ $\angle(\delta_i^{ph-ph} - \theta_i^{ph-ph})$

4. Results and discussion

A load flow analysis based on the backward-forward method is performed on the test system and its results are presented in Table 2. After that, a short circuit analysis according to (Zhang et al., 1995) is performed on the test system without appearance of DGs and its results are illustrated in Fig.2. Settings of protection devices are adjusted, considering load flow and short circuit data. These settings is adjusted according to in such a way that at each fault occurrence, fast operating mode of reclose, corresponded fuses and slow operating mode of reclose act respectively. Parameters of Reclose and fuses are presented in Table 3 and Table 4 respectively.

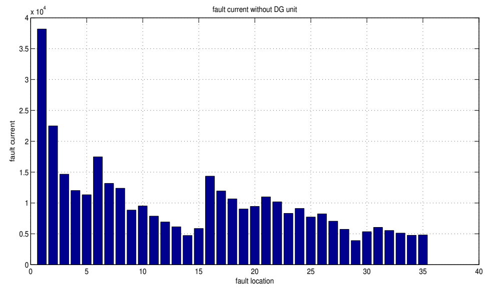

Fig. 2: Fault current of test system in different fault location, without appearance of DG

Table 2: Branch current of the IEEE 37-node test system Without appearance of DG

Branch	From	To	|Ia|	|Ib|	|Ic|
1	1	2	292.6002	255.4866	441.5327
2	2	3	235.9254	198.9604	299.0075
3	3	4	3.150773	33.61441	34.37662
4	4	5	0.013009	0.013053	34.40851
5	5	6	3.179607	33.64298	0.017263
6	6	7	40.06154	98.50018	77.03009
7	7	8	40.08139	98.52043	42.62694
8	8	9	40.27982	8.366168	0.032349
9	9	10	33.50377	0.028257	0.028036
10	8	11	0.206969	90.18501	42.68205
11	11	12	0.055566	17.04811	0.055245
12	12	13	0.015174	17.08185	0.015086
13	11	14	0.097555	73.18196	8.313126
14	14	15	0.041194	16.74812	0.040938
15	14	16	0.006504	56.47557	8.387679
16	3	17	192.8117	66.9448	187.6949
17	17	18	51.27555	17.03318	34.46274
18	18	19	51.28637	17.04405	17.21908
19	19	20	16.93166	0.015213	0.015059
20	19	21	17.1811	17.0725	17.24724
21	17	22	141.6636	50.03962	153.3607
22	22	23	141.697	50.07296	120.1414
23	23	24	0.040189	33.57527	0.040034
24	23	25	141.7415	16.50979	120.1855
25	25	26	0.017244	0.01738	16.92992
26	25	27	141.7737	16.54208	103.2765
27	27	28	107.8969	16.55999	103.2941
28	28	29	0.107607	16.70351	34.54313
29	29	30	0.068868	16.73607	0.06863
30	29	31	0.010761	0.01086	34.62233
31	28	32	108.0178	0.134972	51.48099
32	32	33	51.57465	0.091801	51.5162
33	33	34	0.064145	0.064822	51.5382
34	34	35	0.026699	0.026981	16.92201
35	35	36	0.010746	0.01086	34.64272

Table 3: Reclose parameters

TD_fast	0.45
TD_slow	1.2
A	28
B	0.12
ρ	2
OLF	1.5
I_{nom}	441.5

Fault current in the test system in different fault location, obtained from short circuit analysis in appearance of DG at bus 3 is shown in Fig.3.

Table 4: Fuses parameter

Fuse number	b	Fuse number	b
1	6.2635	11	6.3212
2	6.2387	12	6.1223
3	6.0993	13	6.4324
4	6.2345	14	6.3213
5	6.0938	15	6.2221
6	6.0365	16	6.3214
7	6.4323	17	6.3212
8	6.3412	18	6.3242
9	6.2313	19	6.1211
10	6.4234	20	6.0231

Parameter 'a', for all the fuses, is adjusted to 1.6

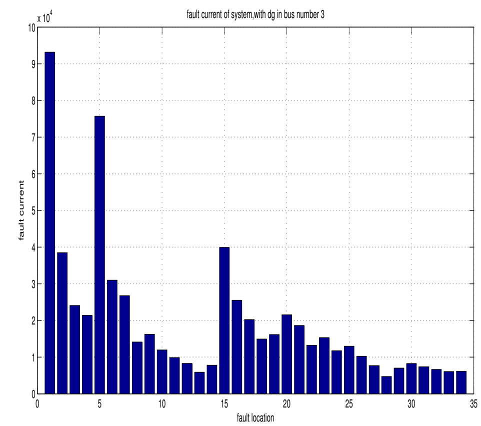

Fig.3: Fault current of test system in different fault location, in appearance of DG at bus 3.

Protection system coordination in test system, in the appearance of DG in different buses, considering fault at each buses is presented in table. 5. These results are more under influence of the Faults which are farther from the main feeder because these faults are more probable.

Table 5: Percent of total protection system Coordination at different DG locations

DG location	%coordination	DG location	%coordination
2	45.44	19	14.98
3	17.46	20	17.32
4	30.07	21	12.98
5	19.78	22	10.32
6	18.67	23	13.23
7	36.98	24	9.67
8	27.43	25	16.54
9	36.98	26	10.89
10	28.39	27	19.19
11	23.39	28	33.12
12	37.65	29	57.34
13	52.12	30	41.23
14	57.98	31	29.76
15	77.24	32	32.87
16	65.13	33	36.26
17	27.34	34	44.37
18	19.89	35	43.64
19	14.98	36	13.46

Mis-coordination in protection system is more due to time interference between fast characteristic reclose and fuses. So for improvement of protection system performance, it is sufficient to change parameter of TD that is corresponded to the fast characteristic of reclose. Its results are presented in Table. 6.

Table 6: Percent of total protection system Coordination At different DG locations and different TD values

FAULT LOCATION	TD=0.1	TD=0.2	TD=0.3	TD=0.35
3	100	96.37	91.67	87.98
4	100	94.98	91.34	85.87
5	94.98	92.12	83.44	65.47
6	93.88	93.21	82.32	65.87
7	98.23	85.37	57.27	44.65
8	100	92.23	81.28	62.36
9	92.29	75.36	39.98	25.36
10	96.36	88.28	69.28	45.38
11	100	100	94.48	82.37
12	88.28	78.28	67.28	45.47
13	91.29	81.28	72.39	54.73
14	88.13	81.29	77.27	72.23
15	77.12	72.37	68.19	38.17
16	67.16	65.37	62.36	48.27
18	96.46	83.21	62.11	52.38
19	97.18	88.21	68.22	56.13
20	90.18	75.28	55.28	29.28
21	88.11	73.21	54.45	28.01
24	81.78	65.09	46.18	32.16
26	77.92	54.58	39.21	29.17
29	73.35	57.39	51.21	45.39
30	67.43	57.98	48.31	35.19
31	62.10	58.02	37.86	27.20
35	70.35	57.64	46.23	36.26
36	68.93	58.91	46.19	47.17

5. Conclusion

A new approach for restoration of protection coordination in appearance of distributed generation is presented in this paper. The proposed method applied to the IEEE 37-node test feeder to assess the impact of the DG penetration on the Pre-installed protection system. Two main steps organize the approach: evaluation of protection coordination at all probable scenarios and improvement of protection coordination. In the first step, status of coordination of protection system is categorized as coordination-hold or coordination-lost group. in this step, all probable scenarios with their probabilities are evaluated. At the second step, after selection of best location for DGs, settings of protection devices are changed if it was needed. The results showed the effectiveness of this method in reduction of protection system miscoordination.

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