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Effect of Wind Decentralized Generation on Contingency Ranking in Power Systems using Fuzzy Logic and MCS

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ABSTRACT

Since power systems are always subject to different contingencies, contingency ranking in power system has special importance. On the other hand, these days, penetration of renewables and decentralized production into power systems is constantly increasing. This paper tries to evaluate the effect of wind decentralized production interfaced with the power system on the contingency ranking analysis. In addition to using fuzzy logic to get a flexibleperformance index(PI), the proposed method is dealing with Monte Carlo Simulation (MCS)-which is one of the best methods to simulate the behavior of stochastic events- to simulate the volatile characteristics of wind Generation. Finally, the proposed method is simulatedon IEEE-Reliability Test System (IEEE-RTS)with satisfactory results. The simulations turn out that an increase in penetration of wind decentralized generation leads to decrease of the PI and the danger of contingencies.

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INTRODUCTION

There is no clear official definition of decentralized production. Generally, decentralized production is defined as the opposite of centralized production. Usually, decentralized generators are not planed in a centralized way, have a power which does not exceed 50 to 100 kW and are scattered over a territory. The development of this type of production can contribute to solving technical, economic and environmental problems [1].

Broadly, reliability indices of a system can be evaluated using one of two basic approaches [2].

- *Analytical techniques:*
- *Stochastic simulation:*

Simulation techniques, estimate the indices by simulating the actual process and random behavior of the system. Volatility is a common feature of almost all renewable energies. Since wind generationhas stochastic behavior too, Monte Carlo Simulation (MCS) which is one of the most powerful methods for statistical analysis of stochastic problems is used to simulate the random amountof the power produced by wind generators.

Penetration of renewable energies and decentralized production into power systems has made considerable effects on many power system aspects. One of these aspects that has been really influenced by renewables is power systems reliability which includes power systems Adequacy and Security. Contingency ranking is one of the ways to evaluate the security level of power systems in which transmission lines exit from the power system make the secontingencies. Generally, to perform this, two methods are common :direct and indirect. Indirect method, changes in one performance index is the indication of contingency danger. In indirect method using fast evaluation methods such as fast load flows, first, post contingency situation is evaluated, then these amounts are placed in a function and ranking is performed.Conventionally, different toolshave been used for contingency rankingsuch as Performance Index [3,4] neural networks [5,6] and fuzzy logic [7]. Indirect methods usually are calculated either in active or reactive domain. While active domain deals with active power flowing through the transmission lines, the magnitude of bus voltages is concerned in reactive domain. Many performance indexes have been suggested for contingency ranking so far. Unfortunately, most of them are rigid and inflexible. In other words, they either consider only the over loaded lines in the performance index, or they treat

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all lines in the performance index the same. The fact that only a small difference in the power flowing through a transmission line, changes that line from totally risky to totally safe, is kind of illogical. While, if all lines (including overloaded and non-overloaded lines)are treated the same inthe performanceindex without considering the increasing amount of power flowinginthem,againan unrealistic approachtotheproblem hashappened. Therefore, in this paper a flexible, fuzzy PI is used to perform contingency ranking.

Although many worthwhile researches have been done so far, this paper is going to evaluate how influential decentralized generation is in power systems security. The research ranks the contingencies that may happen in power systems' transmission lines in presence of one of the most common renewable energies (wind energy), and evaluates the effects of decentralization of this kind of energy on the security of power systems. In section-2, fundamental of wind generation is briefly discussed. Section-3 presents the proposed method;and finally, in section-4numerical studies results are presented and discussed.

2. Wind Generation Basic Concepts:

Wind speed on a specific site varies with the seasons, months, days. After taking measurements on site for a year, the frequency of occurrence of a specific wind speed (i.e. its probability)can be modeled by a Weibull distribution curve. This Weibull distribution of a site enables us to determine the energy that could be produced by the wind turbine for each value of the wind speed. Therefore, unlike conventional power plants and because of random behavior of wind speed, wind turbine often does not operate at its nominal power. In fact, its use is characterized by the Loading Factor (LF) which is defined by the ratio between the number of hours of operation at nominal power (full power) and the number of hours in a year [1]. Obviously, however LF is higher, the potential of generation by wind turbine is increasing. The value of LF could be very varied dependent on time scales and locations. In some windy countries, such as New Zealand, LF can reach above 50% [8].

The gross power in a wind turbine can be written as [1].

$$P_v = \frac{1}{2}\rho\pi R^2 \tag{1}$$

with as air density $(^{kg}/_{m}$ as wind speed (*m/s*) and asblade length (*m*).However, the turbine extracts a mechanical power which is lower than the aerodynamic power. Then, can be defined as the turbine power coefficient:

$$C_p = \quad , \qquad C_p < \tag{2}$$

$$P_m = C_p \frac{1}{2}\rho\pi R^2 \tag{3}$$

According to Betz limit, $C_{p\,r}$ cannot exceed the value of 0.5925 [8].

3. Presentation of the Proposed Method:

Inthispaper, Equation (4) is proposed to calculate the PI in active domain for each contingency. The PI is flexible and fuzzy which includes all transmission lines and treats them according to their over load amount in post-contingency conditions. Meanwhile, the probability of each contingency could be considered independentlyfrom each other.

$$\mathrm{PI} = \left[\sum_{i=1}^{M} \mathrm{W}_i \left[\frac{PL_i}{Pn_i}\right]^{(MFL+2MFM+3MFH)}\right] \times P_{con} + \left[\sum_{i=1}^{M} \mathrm{W}_i\right] \times (1 - P_{cc} \tag{4}$$

$$W_i = \frac{Pn_i}{\sum_{i=1}^{m} l} \tag{5}$$

Where:

Pn_i: Pre-contingency (normal conditions) transmitted power inline *i*

PL_i: Post contingency transmittedpower inline *i*

MFL:Low-loadmembershipfunctionintransmission lines

MFM :Medium-load membership function in transmissionlines

MFH:High-loadmembershipfunctionintransmission lines

M:Numberoflines in whichtheir transmittedpower in post-contingency conditions ismorethantheirtransmission powerinpre-contingency conditions

m: Numberoftotal transmissionlines

W_i:Weight coefficient for line *i*

P_{con}: Probability ofcontingency

Where the amounts of and are determined by DCLF; and MFL, MFM and MFH are derived from Fig.1.

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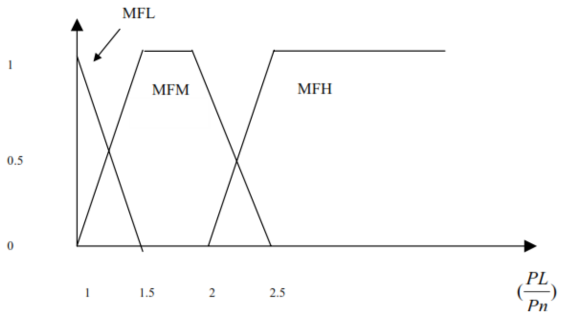

Fig. 1: Membershipfunctionoflow-load,medium-loadandhigh-loadfuzzysetsintransmission lines.

4. Numerical Studies:

In this paper, IEEE-RTS (Fig.2) [3]is used as the case study to evaluate the effect of wind decentralized generation on power systems.

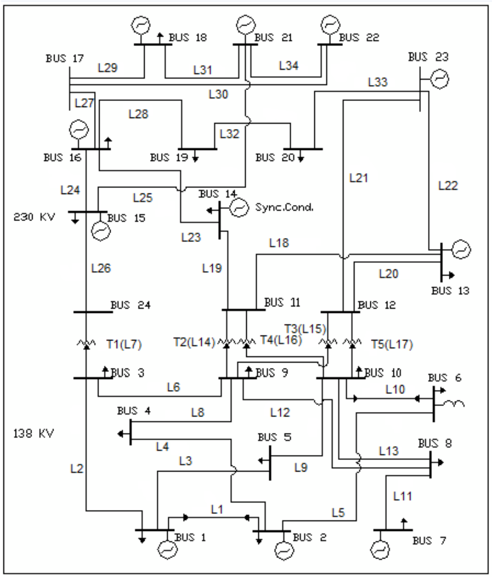

Fig. 2: IEEE Reliability Test System.

Now, three scenarios are considered to evaluate the effect of distributed wind generation on contingency analysis. It is assumedthat the numberof contingenciesis33(including alltransmission linesand transformers, exceptL11). Also, to get clear perception and draw better comparison between all scenarios, let us consider the probability ofall 33contingencies as the same value “1”to providethe same condition for all contingencies to evaluate only the effect of decentralization; (otherwise,according to (4), theprobabilityfor each contingency couldbechosendifferently).

Scenario 1:Base Scenario:

This scenario is modeling the conventional power system without any interfaced wind generation. That is why it is called base scenario. The amount of active power flowing through each transmission line in normal (pre-contingency) condition (*Pn*)is calculated using DCLF as shown in the second and the fifth columns of Table 1. Also, according to (4), PI value for each contingency isevaluated as shown in Table 1.

According to Table 1, transformer 1 (T1) and transmission line 26 (L26) outages could lead to the worst post-contingency conditions in the system. It is notable that in this scenario, the most value for PI is about 6.99, and sum of the PI values is equal to 46.32.

Scenario 2: Penetration of Wind Energy Equals 10% of the Total Generation:

In this scenario, the penetration of wind distributed generation into the conventional power system is assumed to be 10% of the total generation in conventional power system. That means in this scenario, 10% of the generated power in the base scenario is replaced with wind distributed generation. Also, it is assumed that

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the total wind generation capacity is equally distributed among all buses in the system. This scenario is divided into two sub-scenarios:

Table 1: *Pn* and PI values for scenario 1.

Outage Line No.	*Pn*(PU)	PI	Outage Line No.	*Pn*(PU)	PI
7	2.917968	6.988899	9	1.740803	0.72068
26	2.936444	6.960341	15	1.959797	0.687032
25	4.515628	6.680399	29	1.744365	0.61592
27	3.141632	2.792545	12	0.182872	0.595401
33	2.542413	2.468733	22	1.554118	0.57229
23	3.691989	2.460693	13	0.222849	0.568002
17	2.742482	1.064292	3	1.036403	0.557881
1	2.322335	0.935173	28	0.547253	0.542064
2	1.331331	0.9151	4	0.866249	0.541861
32	1.262601	0.908215	14	1.767218	0.535893
16	2.552376	0.847366	6	0.201578	0.524805
21	2.474246	0.811251	30	1.395488	0.521475
19	1.7632	0.810028	20	2.233355	0.506271
18	2.574765	0.75235	5	0.503951	0.456239
8	1.600556	0.750699	31	1.074514	0.39257
10	1.860788	0.74873	24	0.556951	0.34511
34	1.596307	0.740229	Total PI		46.32

Sub-Scenario 2-1: Interfacing Wind Distributed Generation with a Narrow Power System:

In this sub-scenario, LF of each generator at each bus is given by a random number produced by MCS from a Normal distribution function with mean 0.3 and standard deviation 0.05 after 5000 iterations in MCS. Since, in this sub-scenario, the power system is assumed to be situated in a narrow geographic area, the same mean value for LF Normal distribution is considered for all wind generators in the system. According to (4), PI value for each contingency is evaluated as shown in the left side of Table 2.

Table 2: PI values for scenario 2.

Narrow Geographic Area $LR: \mu = 0.3, \sigma = 0.05$				Wide Geographic Area $LR: \mu = [0.2 - 0.4], \sigma = 0.05$			
Outage Line No.	PI	Outage Line No.	PI	Outage Line No.	PI	Outage Line No.	PI
7	6.624097	8	0.508349	7	6.622213	8	0.513966
26	6.408883	29	0.486454	26	6.4358	29	0.497551
25	6.03814	3	0.450001	25	6.038393	3	0.449759
27	2.636509	22	0.420208	27	2.622577	14	0.418903
23	2.311913	14	0.417614	33	2.322181	22	0.412137
33	2.248725	20	0.393424	23	2.307704	20	0.399781
17	0.895338	28	0.372987	17	0.906437	28	0.380006
1	0.830097	30	0.364205	2	0.829969	30	0.360055
2	0.823572	24	0.303212	1	0.82596	24	0.349726
32	0.759291	4	0.279399	32	0.757996	4	0.299496
19	0.742593	34	0.265259	16	0.721946	6	0.27398
16	0.711536	5	0.240368	19	0.671937	5	0.260788
21	0.666552	31	0.225025	21	0.671672	34	0.256447
10	0.615529	6	0.205861	10	0.627784	31	0.253278
9	0.597303	13	0.183712	9	0.598296	13	0.20199
15	0.563584	12	0.161446	15	0.565957	12	0.175078
18	0.536406	Total PI	39.29	18	0.537455	Total PI	39.57

Sub-Scenario 2-2: Interfacing Wind Distributed Generation with a Wide Power System:

Since in this sub-scenario, the power system is considered to be situated in a wide geographic area, the mean value of LF Normal distribution for each generator could be different from each other; and is given by a random number produced by MCS from a Uniformly distribution function ranging [0.2-0.4]. Like the previous sub-scenario, the standard deviation of LF Normal distribution for all generators is still considered to be 0.05. According to (4), PI value for each contingency is evaluated as shown in the right side of Table 2 after 5000 iterations in MCS.

Table 2 turns out that interfacing distributed generation not only improves the total PI, but also decreases the maximum value of PI compared to that of the base scenario. As it was expected in the sub-scenario2-2, since mean value of LF Normal distribution is not as high as that of the scenario 2-1, total PI is a little larger than that of the sub-scenario2-1. Also, comparing two sub-scenarios turns out that there are some differences in the order of dangerous lines between two cases.

Scenario 3: Penetration of Wind Energy=20% Total Generation:

In this scenario, the penetration of distributed wind generation into the conventional power system is assumed to be 20% of the total generation. Like Scenario2, it is assumed that the total wind generation capacity is equally distributed among all buses in the system. Again, this scenario is divided into two sub-scenarios. The number of iterations in MCS for both scenarios would be 5000.

Sub-Scenario 3-1: Interfacing Wind Distributed Generation with a Narrow Power System:

This sub-scenario is exactly the same as sub-scenario 2-1, except the penetration level of wind generation is equal to 20%. According to (4), PI value for each contingency is evaluated as shown in the left side of Table 3.

Table 3: PI values for scenario 3.

Narrow Geographic Area $LR: \mu = 0.3, \sigma = 0.05$				Wide Geographic Area $LR: \mu = [0.2 - 0.4], \sigma = 0.05$			
Outage Line No.	PI	Outage Line No.	PI	Outage Line No.	PI	Outage Line No.	PI
7	6.24942	8	0.424473	7	6.365964	15	0.496763
26	5.83408	29	0.417464	26	6.060637	29	0.459779
25	5.4839	14	0.40639	25	5.7416	22	0.44158
27	2.31488	22	0.395394	27	2.429001	3	0.416286
23	2.13324	30	0.385534	23	2.116694	30	0.413302
33	1.95327	20	0.376497	33	2.084197	14	0.412742
17	0.86282	3	0.35674	17	0.877032	20	0.390468
1	0.70893	28	0.310555	1	0.820706	28	0.339535
2	0.69588	4	0.273648	32	0.725711	24	0.312432
16	0.68604	24	0.258096	2	0.714427	4	0.288919
32	0.63688	31	0.254051	16	0.695869	34	0.281514
21	0.63511	34	0.242772	21	0.674144	31	0.274737
19	0.63499	5	0.190813	19	0.65315	13	0.219286
18	0.54778	6	0.132828	9	0.583987	5	0.217968
10	0.54416	12	0.05729	18	0.579813	6	0.211933
9	0.54075	13	0.05727	10	0.576681	12	0.105419
15	0.48695	Total PI	35.49	8	0.51887	Total PI	37.5

Sub-Scenario 3-2: Interfacing Wind Distributed Generation with a Wide Power System:

This sub-scenario is exactly the same as sub-scenario 2-2, except the penetration level of wind generation is considered 20%. According to (4), PI value for each contingency is evaluated as shown in the right side of Table 3.

As it was expected, comparison between Table 2 and Table 3 turns out that more distributed wind generation penetration into the power system could lead to total PI improving, and also decreasing the maximum value of PI. Also, changes in penetration level can cause changes in the order of dangerous lines.

Generally, as the distributed generators(DGs) increase in a power system, the PI value is decreased. Because in decentralized generation operational conditions, more loads could be fed locally, and therefore the transmitted power through the lines would be lowered. This could be consideredas one of the important effects of decentralized generation and using renewable energies on power systems.

5. Conclusion:

This paper assessed the effect of interfacing distributed wind generation with conventional power systems. The researchused a flexible, fuzzy PI for contingency ranking in active domain. Also, because of volatile characteristic of wind generation, MCS was used to model this purpose. Three scenarios was tested on IEEE-RTS, and following results were concluded:

1- Interfacing distributed wind generation leads to decreasing total PI value and the dangerlevel of contingencies.

2- Combining decentralized wind sources with the power system can result in decreasing the maximum PI value of the dangerous contingency.

3- Changes in penetration level of wind generation can lead to changes in the order of dangerous lines.

Also, these are some proposals for future work:

- Sensitivity analysis to find the efficient bus (or buses) to decrease PI
- Considering other common renewables such as PVs integrated with wind generation
- Evaluatingthe proposed method by offering a PI in reactive domain

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