On-line Risk Assessment on a Power System with High Wind Power Penetration

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Introduction

- By the end of 2012, 75.32GW wind power had been installed in China;
- More than 90% wind power is located in the north of China, far from the load center;
- Most of the conventional thermal generation capacity is coal, and there is little flexible generation;
- With increasing wind penetration, wind power uncertainty has become a major concern for power system security.

Objectives:

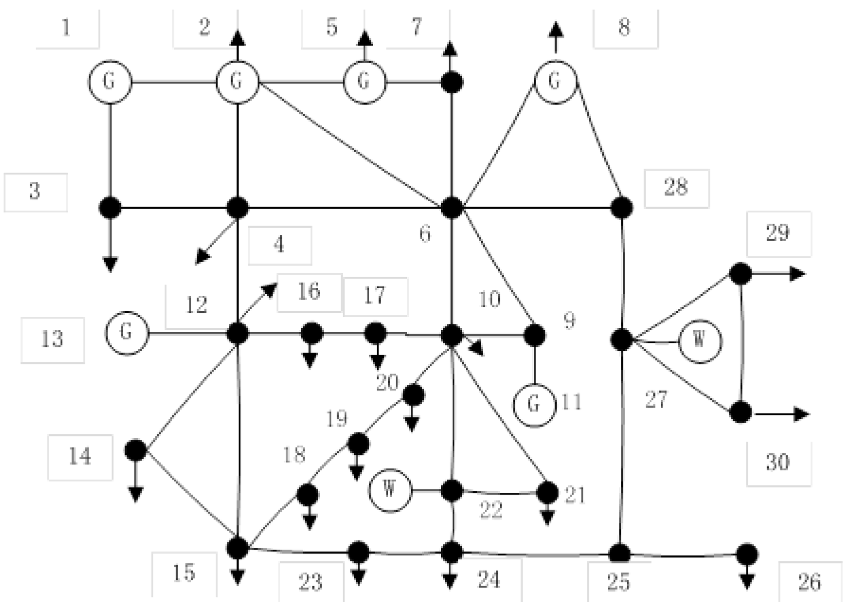
- Determine the risk to system operation quickly;
- Help operators to find solutions to mitigate the risk;
- Focus on flexibility and transmission constraints;
- Consider the uncertainty and correlation of wind power and load.

Methodology

- Latin Hypercube Sampling and ordering matrix is used to consider correlation of wind power and load;
- Ordering matrix is calculated in advance and used directly in on-line system;
- A method for choosing the most critical scenarios is proposed to test the risk quickly.

Test Case

- IEEE30 system with two wind farms;
- Each load and each wind farm are correlated;
- Three methods are used to test the risk for comparison: Monte Carlo Sampling of 100,000 times (MC100,000), Latin Hypercube Sampling of 1,000 (L1000) and 3,000 times (L3000);



- Correlation indicator P_{rms} is used to indicate how the ordering matrix works;

$$P_{rms}=\sqrt{\frac{\sum_{j=2}^{n}\sum_{i=1}^{j-1}(\rho_{ij}-\rho_{ij}')^2}{(n-1)n/2}}$$

- Critical scenarios are selected based on ordering matrix:
  A:[**1**, **2**, 3, ………………n-3, n-2, **n-1**, **n**]
  B:[n-3, 6, **n**, ………………**1**, **n-1**, 13, **2**]

Choose 2 for every value's maximum and minimum as critical scenarios.

Results

- Check if system is at risk with critical scenarios:
- If system is not at risk, operate system normally;
- If system is at risk, then use all scenarios to calculate the risk.

Table 1 Correlation and critical scenarios

Method	Load P_{rms}	Wind power P_{rms}	Number of critical scenarios: Case 1: choose 1 for min and max	Number of critical scenarios: Case 2: choose 2 for min and max
MC100,000	0.0031	0.0016	-	-
L1000	0.0138	0.0002	41	85
L3000	0.0110	0.0006	44	87

Table 2 The result of testing risk

Line		MC	L1000			L3000		
From	To	Overrating %	At risk scenarios number: Case 1	At risk scenarios number: Case 2	Overrating %	At risk scenarios number: Case 1	At risk scenarios number: Case 2	Overrating %
21	22	7.55	4	11	7.70	3	7	8.27
22	24	0.03	0	0	0.00	0	0	0.13
24	25	34.84	12	34	34.20	12	27	34.50
25	27	47.44	12	37	47.00	17	35	47.37
6	28	0.00	0	0	0.00	0	0	0.00

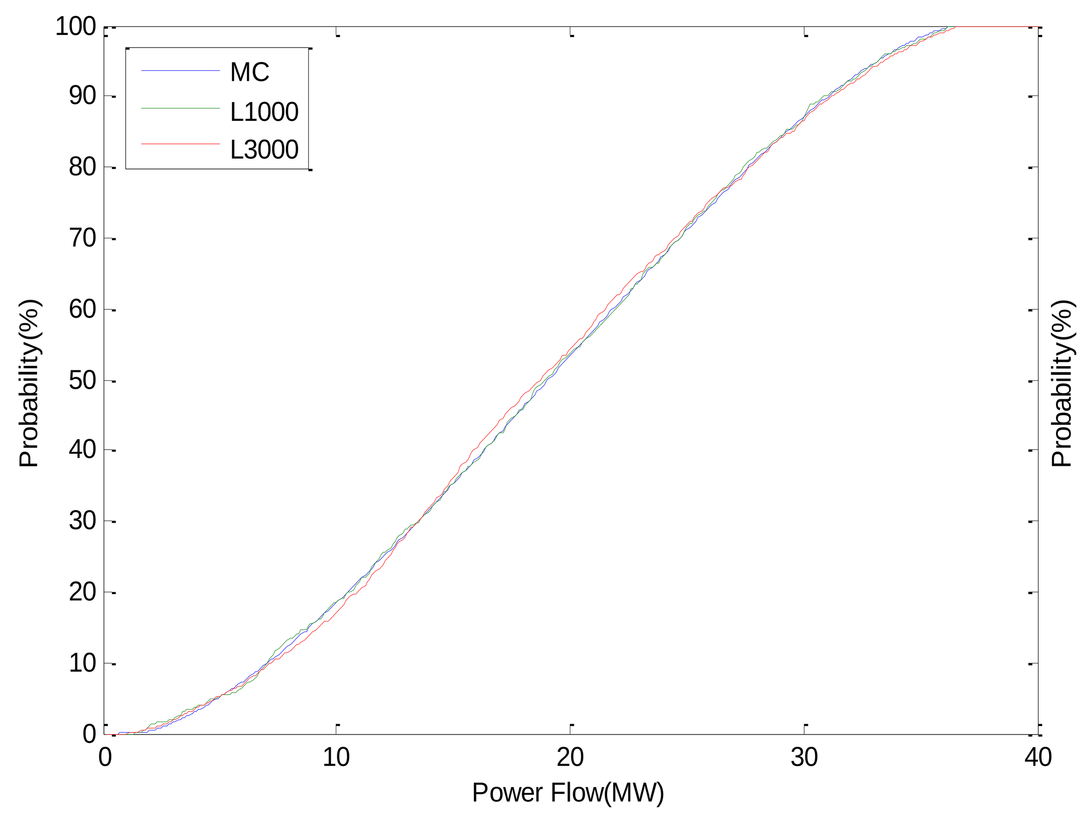


Fig. 1 Cumulative density function for line 21-22 Limited to 32MW

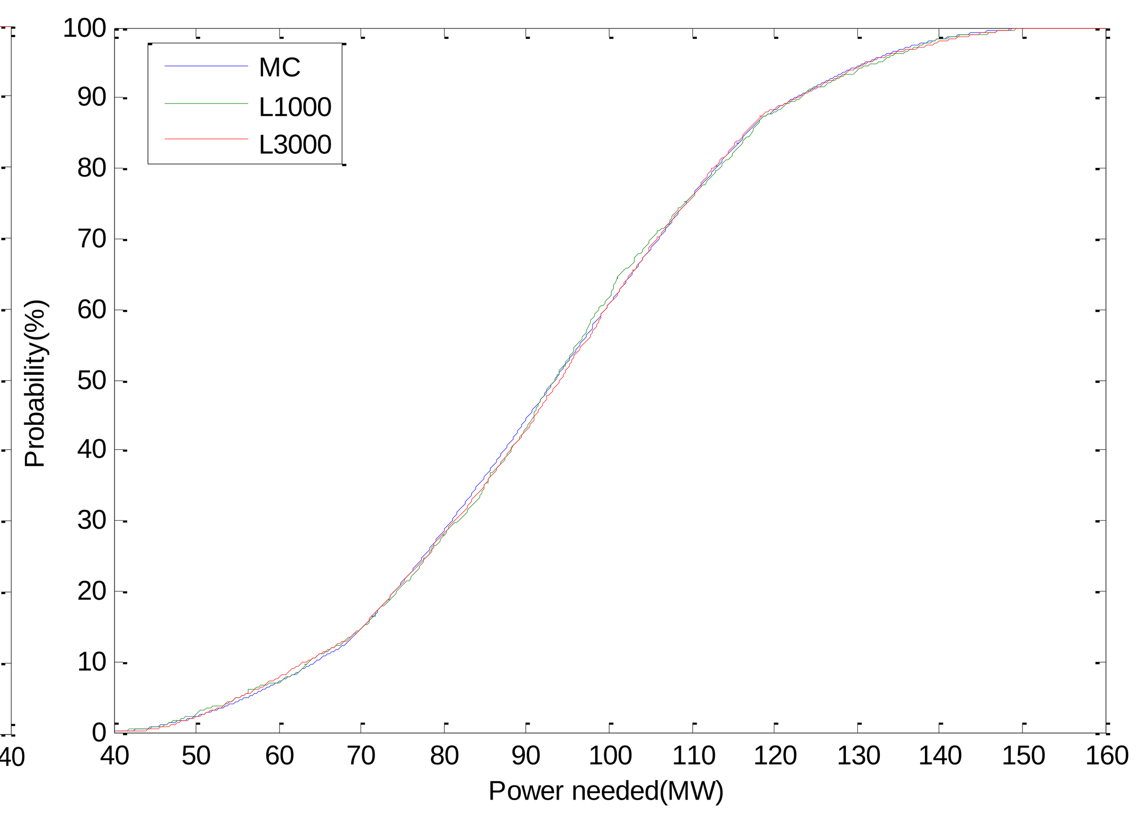


Fig. 2 Cumulative density function for how much generator 1 should output Limited to 68.4-118.4MW

- Taking L3000 as an example, the output of wind farm 1 in the overload scenarios for line 24-25 is 0-50MW, and the output of wind farm 2 is greater than 43.05MW;
- It is assumed that the risk of overloading line 24-25 is caused by too much output from wind farm 2;
- Set 43MW as the limit for the wind farm 2, and then the overload risk is removed from line 24-25.

Conclusions

- **The method for risk assessment works quickly and with acceptable precision. The critical scenarios can find out the risk precisely;**
- **The solution for mitigating risk can be easily obtained from the critical scenarios. While it may not be an optimal solution, it is robust and can be done in real time.**

Acknowledgement

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