Assessment of Sustainable Development of Wind Power Plant

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ABSTRACT

In the last two decades, the wind power generation has been rapidly and widely developed in many regions and countries for tackling the problems of environmental pollution and sustainability of energy supply. However, the high share of intermittent and fluctuating wind power production has also increased the burden of system operator for securing power system reliability during the operational phase. Moreover, the power system restructuring and deregulation have not only introduced the competition for reducing cost but also changed the strategy of reliability evaluation and management of power systems. There are common methods of sustainable development analysis such as survey and experts’ points, net present value (NPV), analytic hierarchy process (AHP), RBF Neural Network, sensitivity analysis, etc. However, the wind power plant assessment is a more complex process, involving various factors and uncertainties [1, 2], fuzzy comprehensive evaluation has a strong nonlinear mapping ability. The paper will apply fuzzy comprehensive evaluation to assess the sustainable development of the wind power plant and carry out examples to show the effectiveness.1

INTRODUCTION

Wind power generation is a promising renewable energy resource, which can compete with conventional power generation in terms of abundance, accessibility and production cost. Wind energy will play an important role in the European Union’s (EU) future energy plan [3]: For example, wind power will provide 50% of electricity production by 2025 [4] in Denmark.

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From the external environment point of view, the sustainable development of the wind power plant mainly includes: wind resource, wind power consumption, wind power plant operation, social, financial status, technical feasibility and environment impact [5]. Wind resource is the result of natural forces created the phenomenon of irregular changes in the harm caused by the wind resource, such as wind power density, average wind speed, turbulence intensity, etc. wind power consumption factors include the wind power limit, peaking power supply and the power transmission capacity[6]; Economic and financial legal risks include changes in economic development, inflation, interest rates, exchange rate volatility, the tax rate change, and patent protection, import and export restrictions, employment restrictions, financial restrictions and restrictions on investment policies; technical feasibility factors include wind farm site selection, technological advancement and the operational reliabilities.; environment impact mainly include the atmospheric protection, water resources protection and the land occupation.

From the internal environment point of view, mainly includes: the inappropriate choice of wind power plant project manager; human resource shortages, unreasonable structure, wind power plant team cohesion is not strong; wind power plant management system is not perfect, and management is not in place, reward and punishment mechanisms are inadequate, cost and schedule management is not scientific; as well as technical barriers to insufficient consideration, insurance, inadequate, etc., which are likely to bring harm to the sustainable development of the wind power plant.

It is important to assess the sustainable development of the wind power plant. For the assessment of the development of the wind power plant, in the use of certain assessment methods and models, it is necessary to establish a certain sustainable development assessment index system in order to reasonably reflect the degree of wind power plant but we cannot cover all of the risk sources. N Company collected the assessment index values of several of wind power plant. The index system is shown as Table I, which is the assessment index system in the paper.

A (very low): \(0.8=Y<1.0\); B (a little low): \(0.6=Y<0.8\); C (general): \(0.4=Y<0.6\); D (a little high): \(0.2=Y<0.4\); E (very high): \(0=Y<0.2\)
<table>
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<tr>
<th>sequence</th>
<th>Primary indicator</th>
<th>Specific indicators</th>
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| X1       | Wind Resource   | 1- Wind power density  
          |                   | 2- Average wind speed  
          |                   | 3- Turbulence intensity  |
| X2       | Wind Power      | 1- Wind power limit  
          | Consumption       | 2- Peaking power supply  
          |                   | 3- Power transmission capacity  |
| X3       | Wind power plant| 1- Advanced technology of wind turbines  
          | operation        | 2- Equipment failure damage rate  
          |                   | 3- Wind power dispatching operation level  |
| X4       | Financial status| 1- Asset-liability ratio  
          |                   | 2- Return on equity  |
| X5       | Technical feasibility| 1- Wind farm site selection  
          |                   | 2- Technological advancement  
          |                   | 3- Operational reliability  |
| X6       | environment impact| 1- Atmospheric protection  
          |                   | 2- Water resources protection  
          |                   | 3- Land occupation  |
| X7       | construct factor| 1-extension of construction  
          |                   | 2- prevent construction  
          |                   | 3-transportation equipment delayed  |
| X8       | quality & safety | 1-design quality and safety  
          | factor           | 2-procurement quality and safety  
          |                   | 3-construction quality and safety  |
| X9       | political factor| 1- social instability  
          |                   | 2- political corruption  |

**THE FUZZY COMPREHENSIVE EVALUATION OF WIND POWER PLANT**

Through the classified summary, I put the nine risk factors fall into the following and label systems to facilitate the follow-up study:

1. wind power plant system R1: Wind Resource R11; Wind Power Consumption R12; Wind power plant operation R13;
2. Economical Environmental Systems R2: Financial status R21; Technical feasibility R22; environment impact R23;
3. Construction system R3: project delayed R31; extension of construction R32; quality & safety risks R33;
4. Process Systems R4: contract R41; design R42; construct R43;

Determine the evaluation risk range V: Divided into five grades of sustainable development very high V1; a little high V2; general V3; a little low V4; very low V5.

Determine the comparison matrix Xi (i=1, 2, 3, 4): Based on the external environment and the situation of the wind power plant, the experts of N company carefully vote for the wind power plant levels (Issued a total of 25 usable tables 20), statistical results is in Table 1.
Using Zadeh operator $M(\land, \lor)$, then the Two indicators of evaluation factors set is: $B_{i} = A_{i} \cdot R_{i}$

$$
\begin{bmatrix}
B_{1} \\
B_{2} \\
B_{3} \\
B_{4}
\end{bmatrix} = 
\begin{bmatrix}
0.1 & 0.3 & 0.5 & 0.33 & 0.33 \\
0.1 & 0.28 & 0.45 & 0.3 & 0.27 \\
0.25 & 0.35 & 0.30 & 0.40 & 0.20 \\
0.30 & 0.25 & 0.35 & 0.37 & 0.1
\end{bmatrix}
$$

Normalized:

$$
\begin{bmatrix}
0.06 & 0.19 & 0.32 & 0.21 & 0.21 \\
0.07 & 0.20 & 0.32 & 0.21 & 0.19 \\
0.17 & 0.23 & 0.20 & 0.27 & 0.13 \\
0.22 & 0.18 & 0.26 & 0.27 & 0.07
\end{bmatrix}
$$

Continue using fuzzy Zadeh operators to computing and getting the set of indicators for evaluation of factors:

$$
B = Q \ast R = (0.28 \ 0.31 \ 0.19 \ 0.22) \ast
\begin{bmatrix}
0.06 & 0.19 & 0.32 & 0.21 & 0.21 \\
0.07 & 0.20 & 0.32 & 0.21 & 0.19 \\
0.17 & 0.23 & 0.20 & 0.27 & 0.13 \\
0.22 & 0.18 & 0.26 & 0.27 & 0.07
\end{bmatrix}
$$

Normalized $B^* = (0.19 \ 0.17 \ 0.27 \ 0.19 \ 0.18)$

**CONCLUSIONS**

So in accordance with the principle of maximum degree of membership the Max is 0.27. Based on the above level of the sustainable development we get the evaluation result is 0.27. So we can get the outcome is that: the sustainable development of the wind power plant level is between general and a little low range,
then we get the result that: the sustainable development is moderate and the wind power plant can sustainable to develop.

REFERENCES