Abstract

Distributed wind power has received growing attention in recent years. However, high risks remain in its investigation, which severely baffled its development. This study attempts to gather and identify risk factors in distributed wind power through literature reviews and rank the risks based on expert opinions. Based on previous literature, we classified risk for distributed wind power investment into four types, namely the political risks, economic risks, social risks, and technical risks. Analytic Hierarchy Process (AHP) method is used to assess risks in the life cycle of the distributed wind farm. Political, Economic, Social and Technical methodology as the criteria hierarchy is introduced to classify the identified risks as the sub-criteria hierarchy in the AHP model. The result shows that the risk of changes in electricity price policy is the most critical impact on the distributed wind power system to obtain sustainable development and make profits. Therefore, the government needs to provide a long-term vision of electricity price policy to promote the development of distributed wind projects.

Keywords: Distributed Wind Energy; Risk Management; PEST Analysis; Analytic Hierarchy Process (AHP); Quantitative Risk Analysis

1. Introduction

China is forcing to change its energy development strategy to replace conventional power plants (Zhao, et al., 2014; Tang & Popp, 2016). In China’s National 13th Five-Year Plan for Renewable Energy, the government intends to increase the capacity of the wind power to 210 GW and adds the capability of solar power to 110 GW by 2020 (Mathews, 2017). In 2017, China's total wind power production was 303,420 GWh, accounting for 4.73% of the entire power generation and occupying about two-thirds of power generation of all renewable energy (including solar, biomass and wind power) (State Grid Energy Research Institute, 2017). The present context of China’s wind power is that the rate of abandoned wind farms in the ‘Three North’s region’ is high. The transmission expense increases the generation cost of wind farms as the wind parks are far away from the load centre. Driven by technological progress, the growth of energy requirements and numerous incentive policies, especially the “Interim Measures for the Development and Construction of Distributed Wind Power Projects” published, the Chinese energy companies and relevant suppliers have been attracted by the distributed renewable energy (DRE). The development of the future energy system is imperative for a country. However, the sustainable energy system by itself cannot promise a maintainable development due to the consideration of technical and financial factors (Guerrero-Liquet, et al., 2016). According to the latest plans and policies of the Chinese government, the distributed wind power project can have a total capacity of no more than 50 megawatts (MW) of grid connection points and an access voltage level of 110 kV (66 kV in Northeast China). Distributed generation systems generally select the location close to the point of consumption, on the customer side of the metre or the distribution network (Allan, et al., 2015). Distributed generation can apply its advantage of the location to assist the distribution system in decreasing the peak load capacity and delaying the demand for substation capacity extension (Del Monaco, 2001). The location of the distributed wind farm has the advantage of increasing land use and saving the cost of the transmission line (Drugmand & Stori, 2017). According to the study of Zhu et al. (2017), nineteen provinces in central, eastern and southern China possess the low-speed wind resources that can exploit the wind energy programs. Meanwhile, the Chinese government launches a set of policies that encourage the company and enterprise exploring the potentials of the distributed wind power. The latest policy released by the National Energy Administrator attracts more non-power firms and private investments that ask the organisation to have a professional management system to pursue sustainable development.

A few pieces of research focused on exploring the risk management employed in the wind farm, and the papers about the risk management of the distributed wind power are much rarer (Chou & Tu, 2011; Li, et al., 2014; Gatzert & Kosub, 2016; Rolik, 2017). The research of Chou and Tu (2014) concentrates on a particular case – the tower collapses. However, many other risks that may cause more cost and losses for the power companies have not been considered. The company that invests in this new type of energy project is more sensitive to the risks than the conventional wind farm. According to the statistic latest of the National Energy Administration, fifteen distributed wind parks are in commission, and an additional three projects are in the planning (State Grid Energy Research Institute, 2017).

Therefore, this paper systematically reviews the development status of existing distributed wind power in China through literature reviews, and issues questionnaires to eighty-five experts in the wind power field. The risk factors associated with political, economic, social and technical fields of the distributed wind power system are gathered through literature reviews and interviews. The AHP method is used to evaluate the experts and comprehensively evaluate the existence of distributed wind risk points. The results can assist enterprises in the distributed wind power industry to better identify risks and help the government in formulating relevant policies.

2. Risk management in distributed wind power

In the literature, various papers claim that the completed risk management process involves four key phases which are risk identification, risk analysis, risk treatment and monitoring and review (Cooper, et al., 2005; ISO, 2009; Kendrick, 2015). Distributed wind power is a new electricity production model that has only emerged in recent years. The published articles on the distributed energy systems focus on the definition of this conception and the qualitative analysis of their barriers (Pepermans, et al., 2005; Alanne & Saari, 2006; Perera, 2016). However, quantitative risk management research on distributed wind energy is difficult to find in publications. The distributed wind park settles closer to the end users than the traditional wind farm. It leads to potential hazards not appearing in the large-scale wind park, which is the objective of this research. Therefore, this study purposes for identifying risks and analysing their influences in the distributed wind energy project.

Risk identification is a systematic and continuous process that identifies, classifies and evaluates all the potential hazards and damages which are learnt from the past projects or undetected events or consequences through keeping attention for documentation of new risks during the through-life cycle of the project (Ameyaw & Chan, 2015; Tchankova, 2002; Harland, et al., 2003). Literature research and interviewing project personnel who have experience with similar projects are effective methods to gather correct risk elements (Tadayon, et al., 2012). SWOT analysis attempts to assess the sustainable development of an organisation by investigating both the internal and external factors (Zhao, et al., 2013). PEST analysis emphasises the effect of external macroeconomic factors on a project or an industry (Barbara, et al., 2017). It is inappropriate to implement SWOT analysis to deliberate the distributed wind power industry. The consequence of this research should be suitable for the whole DWP project in China. Previous publications implement Real Options Analysis (ROA), Failure Modes and

Effects Analysis (FMEA) or Fuzzy Neural Networks to assess the operational and financial risks in wind power project (Muñoz, et al., 2011; Shafiee & Dinmohammadi, 2014; Pinson & Kariniotakis, 2003; Munoz, et al., 2009). However, the ROA method is complicated for managers to gather data that can support the assumption (Kind, et al., 2018). FMEA needs to consider the Risk-Priority-Number (RPN) values. Various wind turbines have different structures, which leads that the RPN values between different wind turbines cannot be contrasted (Shafiee & Dinmohammadi, 2014). Large wind farms and distributed wind parks have several similarities. Hence, the risks that appeared in the large wind farms can present references to the distributed wind power project. The risk factors gathered from the traditional wind farm are classified as political risks, economic risks, social risks, and technical risks.

Political risks are composed of the government regulations and rules, the taxation rate policies (i.e. tax, exemptions), fiscal policies and environmental laws. that may affect the specific industry and business to a large extent (Kolios & Read, 2013). The conventional power generation technology still has its superiorities that wind power cannot substitute. Prässler and Schaechtele (2012) argue that the sustainable development of wind energy needs policy support from the government (Prässler & Schaechtele, 2012). Renewable Energy Laws released by China's commitment present a positive attitude to the electric power enterprises (Wang, et al., 2010). Fagiani, et al. (2013) explore the impact of feed-in tariffs and certificate markets on the sustainability of renewable energy development. (Fagiani, et al., 2013)

Economic risks gauge the economic environment through analysing the macroeconomic such as supply and demand, exchange rates, interest rates, and credit risks (Erb, et al., 1996). The cost of electricity and the capital expense (CAPEX) are used to evaluate the economy of wind power (Weaver, 2012; Moné, et al., 2017). The investors pay attention to the profit, and customers care about the price of electricity. Whereas the stakeholders are more interested in lower CAPEX (Gupta, 2013; Barba, et al., 2016).

Social risks are identified through in-depth investigations of numerous social and environmental aspects including climate changes, the purchasing power of target customers, community infrastructure, demographic, environmental damage and pollution (Zalengera, et al., 2014; Michelez, et al., 2010). The well-designed circumstances and well-performed social planning can mitigate social conflicts, control the potential risks for investors and protect the environment (Michelez, et al., 2010). Zalengera, et al. (2014) observes that the labour requirements, skill, and knowledge training should be noticed in social risk management.

Technical risks distribute to various classes that involve technological innovations, completed investment estimates, challenging project management (i.e. construction, O&M and connection issues) and efficiency and capacity factors (Michelez, et al., 2010; Zalengera, et al., 2014; Rastogi & Trivedi, 2016). Technical risks may cause a positive or negative consequence for the operation of the wind turbine industry and distributed wind power market. Modern living relies on electricity. Nevertheless, the inappropriate form of energy may be hard to suit the local needs of the electricity and cause the losses of the power company (Gatzert & Kosub, 2016).

The risk analysis of the project is an effective method to make decisions on the best strategies and ensure that the project is profitable (Anca, et al., 2015; de Oliveira, et al., 2017). Risk analysis can estimate the period of the identified events and the extent of their influence through a systematic investigation of available information (Cooper, et al., 2005). Qualitative risk analysis assists the related organisation to figure out the most critical risks by rank-ordering them and pay attention to the solution of the high-prioritised risks to enhance the performance of the project (Mojtahedi, et al., 2010). Whereas, quantitative risk analysis is a numerical analysis to calculate the probability and consequence caused by all the individual risks and other uncertain factors of the project through implementing mathematical models and simulation tools (Michelez, et al., 2010; Project Management Institute, 2017). The implementation of the tools and techniques for the quantitative risk analysis can estimate the results under complicated scenarios and limited data (Modarres, 2016). PEST analysis covers the macroenvironmental factors that influence the sustainable development of the renewable energy sector (Igliński, et al., 2016). The most versatile analysis approach in the energy area is the Analytical Hierarchy Process (AHP) as it can convert a complex issue into a simple hierarchy, flexibility and intuition (Pohekar & Ramachandran, 2004; Linares, 2002). AHP method expresses a quantitative analysis of the risks that hides among the whole-life cycle of the wind power project (Jin, et al., 2014). It is easy for decision-makers to weight and compares two alternatives. It is also free to adjust in size to fit decision-making issues (Velasquez & Hester, 2013).

Distributed wind power is a new electricity production model that has only emerged in recent years. The published articles on the distributed energy systems focus on the definition of this conception and the qualitative analysis of their barriers (Pepermans, et al., 2005; Alanne & Saari, 2006; Perera, 2016). However, quantitative risk management research on distributed wind energy is difficult to find in publications. The distributed wind park settles closer to the end users than the traditional wind farm. It leads to potential hazards not appearing in the large-scale wind park, which is the objective of this research.

3. Research Methodology

Systematic risk management can remove potential risks in the renewable energy industry and create more benefits for the firm. For research methodology, bibliography reviews can distinguish what has been studied and figured out on the topic. This step is impossible to be ignored for the determination of research topics as it prevents researchers from repeating the study that has been done (Budgen & Brereton, 2006). The purpose of literature reviews is an extensive overview of research focused on the fields that few people are involved (Mardani, et al., 2017). This article proposes an MCDM-based approach to assess the risk of distributed renewable energy.

The risk management in the distributed renewable energy industry is still blank. However, the dominant influence of income is types of risks, such as policy risk, cost risk, construction risk, and technical risk. Distributed renewable energy provides an unprecedented chance for developing countries to obtain clean energy. The problem is how to offer an affordable electricity price for the customer and guarantees that the distributed renewable energy company has revenue. The total funding of distributed renewable energy from various organisations and donors between 2012 and 2017 has reached approximate GBP 700 million (Zervos & Adib, 2018). The distributed renewable energy program is attracting investments from government institutions and competitive enterprises.

The contribution proposed by literature research is to verify that the MCDM method, especially the AHP approach, is suitable for the technical risk assessment phase. The fundamental steps of the study described in Figure 1 display an overview of the methodology for discussing how to apply the AHP method to improve the sustainability of the distributed renewable energy project.

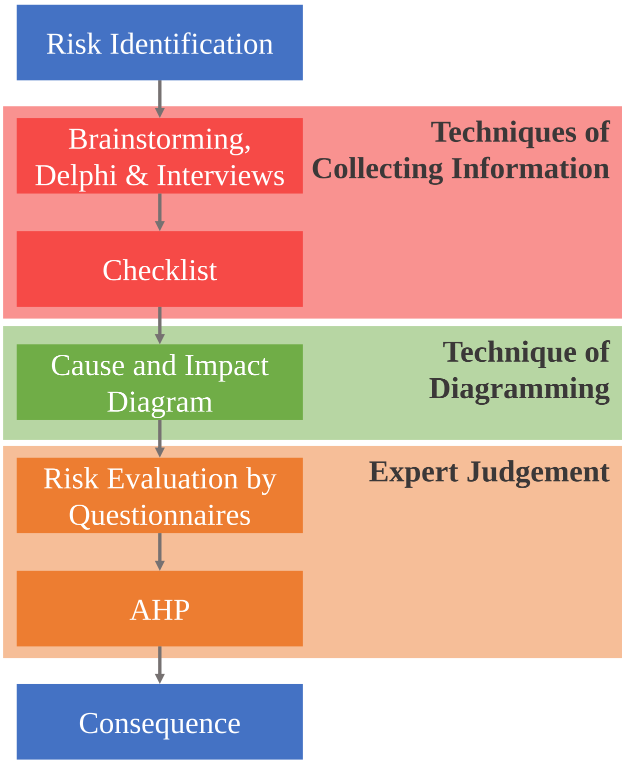

Figure 1 An Overview of the Methodology of the Research

The PEST analysis is the most common means to reflect the external environment of the industry and a helpful strategic tool for seeking business position, potential market and the trend of the development (Gupta, 2013; Koumparoulis, 2013). Political analysis generally focuses on the changes in the domestic policies, local policies and government subsidies on investment and taxation. The economic phase determines whether the distributed wind power project is successful and profitable or not. The industry or organisation should consider the social influence of the new business appearance. Technology changes result that the firm owns competitive advantages in the industry.

AHP method mixes qualitative and quantitative criteria and internal and external effects to meet the requirement of the decision maker. In this study, the AHP method is used to deal with the comparison, weighing and ranking of identified risks in a distributed wind energy project. The first step is to build the Judgement Matrices that an element of the above layer as a criterion for judging the element value determined by the pairwise comparison of the underlying components. The Judgement Matrix is an n × n matrix, shown as the example of Matrix A below:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & \vdots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{11} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

In the AHP analysis method, the most fundamental computational task is to resolve the largest eigenvalue (λ_{max}) of the Judgment Matrix and its corresponding eigenvector (W). The Judgment Matrix itself is the result of quantifying the qualitative problem. Hence, the calculation of the maximum eigenvalue and eigenvector of the Judgment Matrix allows a specific error range. The relationship of weight vector (ω), λ_{max} and matrix A can be presented as:

$$A\omega = \lambda_{max} \cdot \omega \quad (2)$$

Then, the weight vector needs to be normalised to achieve the matrix for a priority order.

The procedure of the pairwise comparison while filling the questionnaire survey involves the subjective judgment of the responder. Therefore, the situation of the inconsistency may happen. It is an essential stage for the AHP analysis as the wrong Judgement Matrix causes the mistake of making decisions. The consistency index (C.I.) demonstrates the degree of compatibility deviation. The expression of C.I. is presented as:

$$C.I. = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

Where n is the number of the evaluated factors in the Judgement Matrix.

The largest eigenvalue is defined as:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(A\omega)_i}{\omega_i} \quad (4)$$

Consistency Ratio (C.R.) is introduced as the criterion of the consistency index. The expression is defined as:

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

If $C.R. > 0$ and $C.R. < 0.10$, then the weight vector ω is an appropriate solution and Judgement Matrix is a satisfactory consistency matrix. When C.R. is zero, it means that the Judgement Matrix is a complete consistency matrix.

The last step is to calculate the global weight which illustrates the influence level of sub-risk factors in the overall project. Global weight is equal to the local weight of each sub-factors multiplied by the local weight of its corresponding criteria of the element.

Risk identification is the first stage of risk management. It is crucial for complete research as risk analysis is meaningful after meeting the scenario of the correctly-identified risks. The means of risk determination is through searching from the previous relative papers and interviews to collect the judgements of experts and associated practitioners. Political, Economic, Social and Technical factors are the four primary criteria that decompose the gathered risks into four groups. PEST technique is an analysis framework of strategic management to recognise the risks and evaluate the influence of construction projects (Rastogi & Trivedi, 2016). The distributed wind energy is an emerging industry that leads to a lack of relevant reference. Therefore, the most risks lesson from the experience of other sorts of enterprises and organisations through a structured documentation review. The risks can be transferred from large-scale onshore and offshore wind farms. The additional risks are gathered from the interview with general managers. The next stage is to summarise the risks and implement the checklist technique. Then, a questionnaire is performed to invite the professionals and managers to evaluate the influence of the risks to the system from the Political, Economic, Social and Technical perspectives. The criterion of the judgement refers to the Saaty's scale, as exhibited in Table 1. The results of the questionnaire set as the inputs of the AHP analysis.

Despite the many advantages of AHP, there are still many limitations. it is difficult for participants to reach a unified standard that they can map their own subjective opinion into a number (Kwong & Bai, 2002). Li, et al. (2008) argue that AHP cannot present the inherent characteristics of complicated evaluation problems, which results in the issue of incorrect rankings. AHP lacks the capability of prioritizing two alternatives with different weights at a different time (Ahmad, et al., 2010)

Table 1 The Criterion of the Effect of Risk (Saaty, 1990)

Intensity of Importance	**Definition**
1	Equal importance
3	Somewhat more important
5	Much more important
7	Very much more important
9	Absolutely more important
2, 4, 6, 8	Intermediate values between the two adjacent judgments

4. Data Analysis by AHP Method

4.2 Risk Identification of Distributed Wind Power in China

The purpose of this research is to aid with the DRE companies to obtain a sustainable development in the future of the Chinese electricity market, which is the top hierarchy in the model. The uncertain factor is the risks that hide in the through-life cycle of the project. The risks found in the bibliography or discussed by interviews are tailored to fit the conditions of the distributed wind energy project. The cluster of the risks decomposes into four entities (including Political, Economic, Social and Technical). The AHP model is an entirely independent structure that owns substantive risk factors underlying the PEST groups. The sub-factors of the risk factor are the descriptions of the risk reasons on the third level. Figure 2 demonstrates an overview of the AHP model for the risk management of distributed wind power projects.

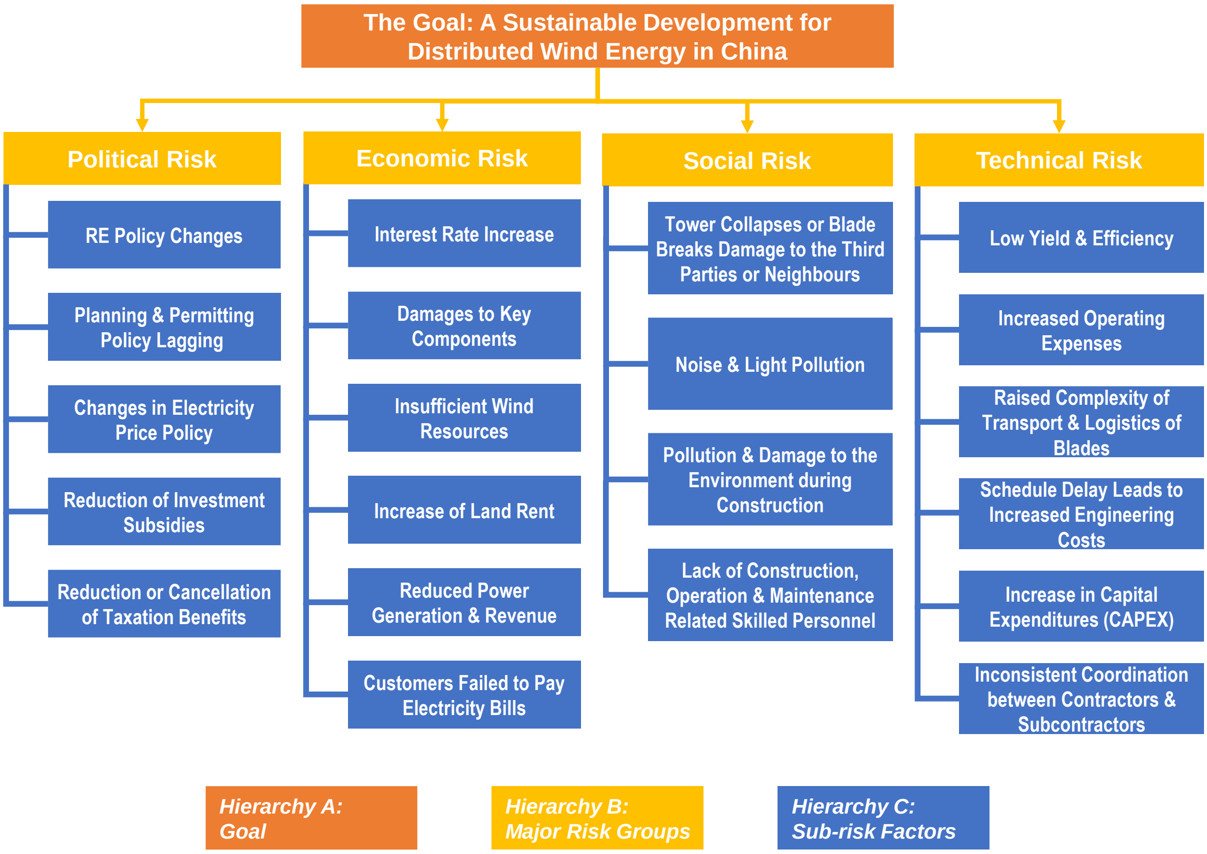

Figure 2 AHP Model for Risk Assessment

The delivery and collection of the questionnaire use the method of emails. Then, summarise the data and calculate the magnitude of pairwise comparison by the geometric mean way. The detailed treatment of these results will be discussed in section 0.

4.2 Questionnaire Data Collection

In this study, a total of eighty-five questionnaires were recovered from twenty-three provinces in China. Figure 3 expresses that twenty-six of the responders are he general manager and twenty-seven persons are the senior expert on the renewable energy industry. The most portion of the respondents is the ones who are both manager and expert. The fifty-nine in eighty-five interviewees have more than five years of experience in the wind power industry, as shown in Table 2. Thirty-five participants in this questionnaire have the job engaged in the distributed wind energy industry. From another perspective, it emphasizes that the distributed wind power is still in the beginning stage in China.

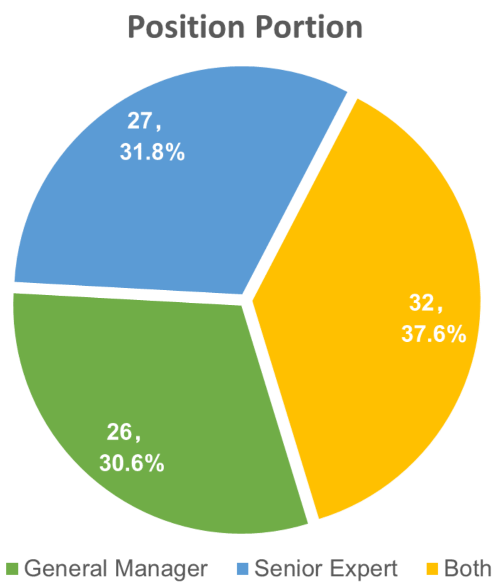

Figure 3 Occupation and Tile of the Respondents

Table 2 The Basic Statistic of the Respondents

No. of Years of Experience in Wind Power Industry	**No. of People**
2-5 Years	27
More Than 5 Years	58
Have Ever Engaged in Distributed Wind Power?	No. of People
Yes	35
No	50

The errors of the judgment are inevitable since it is a process of subjective evaluation by experts. In order to reduce the probability of inconsistency of the matrix, the largest and the smallest assessment scores in the cluster of the same pairwise comparison of the risks are removed before estimating the geometric mean.

5. Results

The consequence of risk assessment debates depended on the hierarchical groups. The identified risks divide into four clusters (including Political risks, Economic risks, Social risks, and Technical risks). Table *3* indicates that the Political risks are the most critical cluster in this hierarchy, which takes approximately 38.96%. The impacts of Economic, Social and Technical risks for the project are similarly equivalent, which occupy around 20%. The table indicates that the stakeholders believe that the development of the distributed wind energy industry has a strong affiliation with the control by the Chinese government. A definite incentive policy can encourage more firms to invest in distributed wind energy projects. The government has the responsibility to discipline and guide the development scale, speed and operation management of the wind power industry. However, the cancellation of the preferential policy may lead to income decrease. The current situation of China is that the government inspires electric power companies or other firms about distributed wind power to notice this new industry. The second risk is the Social Risks. Two major risks in the political field are the risk "Changes in electricity price policy" and "Renewable Energy Policy Changes". The net profit of a company is the difference between profit and taxation. The profit consists of the income of the primary business and various subsidies minus cost and tax expenses. The performance, income, and cost have almost fixed when the project construction is completed and put into operation.

Table 3 The Overview of Risk Assessment

Political	**38.96%**	**Economic**	**19.68%**	**Social**	**22.68%**	**Technical**	**18.68%**
R1	26.31%	R6	12.91%	R12	44.60%	R16	30.17%
R2	13.16%	R7	13.34%	R13	21.72%	R17	12.47%
R3	29.91%	R8	25.77%	R14	15.24%	R18	13.21%
R4	15.85%	R9	11.29%	R15	18.45%	R19	10.84%
R5	14.77%	R10	19.18%			R20	12.47%
		R11	17.50%			R21	12.47%

Hence, the most sensitive content for the distributed wind parks is the fluctuation of the electricity price and the changes in subsidy policy. The issue of the lack of persistence for the government subsidies results in a decrease in the profit of the firm or a loss of the company due to the uncertainty of wind power policy in China and the reform of the market mechanism. These risks mostly have regular patterns. For example, the purpose of the RE policy changes is to control the aggregate volume of wind energy or other renewable energy directly. The Chinese government would retard the speed of developing new wind farm projects if the current capacity exceeds the amount of government planning. The changes in investment subsidy and tax benefits are the indirect regulation measures to make investors lose interest in wind power projects. The wind turbine may have an impact on the natural scenery, resulting in low acceptance of the project. There is a case that small wind power equipment was set up in the scenic spot in China. However, the wind turbine ultimately demolished due to destroying the original scenery.

Economic risks are concerned about the economic benefits of the project. These respondents have evaluated the critical reasons for weak profitability. The most significant risk factor is the risk "Load hour is lower than the planning value due to the poor wind resources". The weak wind resource raises the capital cost per kW and causes low load factors in the small-scale wind turbine. It is more necessary for the low-wind-speed area, compared to rich wind resources and high-wind-speed region, to notice this risk while deciding on the wind farm site. The client turnover (R10) and electricity bill recovery (R11) issues are the potential risks that only happens in the distributed generation system. The project manager needs to perform an abundant investigation on the population distribution, the payment ability, and credits of the clients and the enterprise during the design phase of the project. The other risks are the low risks that have a minor impact on the project. The risks of increased interest rate and the fee of the land lease are beyond the management control. The construction and logistics industries have been comparatively mature in China. Therefore, the core component damage during these phases is low occurrence possibility.

Social risk is the second vital risk among the PEST hierarchy. The weight of "The tower collapses, fire or the blade break damage to the third parties or neighbours" risk reaches an astonishing 44.60%. This risk can lead to the destruction of surrounding buildings and severe casualties as its location is closer to consumers than the large-scale wind park. The quantity of the wind turbine in the distributed renewable energy system is limited. Therefore, the losses caused by the breakdown of one wind turbine in a distributed wind park is more grievous than the same situation happened in a large-scale wind farm. The noise and light pollution for natural livings and human beings is the next consideration. The noise mostly comes from the wind blades and the gearbox of the wind turbine. The wind park will directly affect the bird's activity when it is running since some birds including poultry are sensitive to noise and light, which may result in civil compensation, increasing operating expenditures.

The Technical risks are defined as the minimum influence in the distributed wind power system. The principal technical risk is the risk "Yield and effectiveness are lower than the design value (R16)" that causes the decline of the income. The reason may be the mistake of the design engineer. The lousy weather for the period of the construction and operating phases can lead to an increase in CAPEX, construction cost and the expense of the commissioning. The weight of the blade transportation problem ranks the last one in technical risks. Most of the questionnaire participants agree that the technology of wind blade transportation can reduce the construction cost and fit the narrow roads in the urban or intensive industrial park. However, transportation safety should retain attention as any of the accidents may lead to massive losses.

The principal risks are from the political factor. However, these risks are unpredictable, and the team cannot intervene previously. Hence, the risk management strategy of the distributed wind power project is to mitigate or eliminate other three-group risks to guarantee the maximum value delivering to stakeholders.

6. Discussion

The electricity price policy of wind energy in China appears downtrend annually. According to the latest policy from the National Development and Reform Commission, the net price of onshore wind power in 2019 is from approximate 0.05 US dollars to 0.08 US dollars. To 2020, it will drop to around 0.04 to 0.07 US dollars. Twelfth of thirty-four provinces have published their local development plan on the distributed wind power. Encouragement and openness attitudes towards distributed wind energy are such good information guiding electricity firms to enlarge the market in the era when the conventional wind energy market has been saturated. Therefore, this study becomes essential to assist renewable energy companies to figure out the potential risks of the distributed wind farm project. The government should not imitate the development model of a traditional wind power project. For instance, the approval requirements and processes for traditional wind power development waste a lot of time led to construction inefficiency and raised initial costs of the distributed wind power project.

Another concern is the hidden dangers of the tower collapses, fire and the blade break damage to the third parties or the neighbours. The economic loss caused by the accidents described above may turn into an invisible and uncertain cost. More importantly, the social issues associated with casualties of citizens or people in manufactory may result that the government has to stop the development of the distributed wind power.

The distributed wind farm has the characteristics of scattered layout and small scale. This study prefers that the government should conduct centralized planning to reach economic and efficient management and ensure the well-ordered development of the project. The Chinese government can refer to the experience of the Danish community-owned wind project, which utilizes a public-private partnership (PPP) model to decrease the interest cost (Maegaard &

Gorroño, 2016). Distributed wind power proposes higher requirements on the wind turbine in the technical field. A good-quality wind turbine can significantly save operation and maintenance costs. Long-tern financial subsidy policy is unstable in the future. However, the new technology could reduce the construction period and cut the cost of the distributed wind project.

7. Conclusions and Future Work

7.1 Conclusion

Firstly, this article offers a detailed and comprehensive description of the current status and the development of wind power in China. The common risks happened in both conventional wind farm, and the distributed wind farm can be found from the literature review. The potential risks in the distributed wind energy are identified through the interview with the managers of Chinese renewable energy companies. These risk factors are the problems that need to resolve now or in the future or not exist in conventional wind power projects. Then, this study introduces an approach to utilising PEST as criteria for the risk classification method to structure the AHP model. A questionnaire evaluates the pairwise comparison of risk influence. The result of AHP for risk assessment determines that the risk of changes in electricity price policy estimates as the most majority impact for the distributed wind power system to obtain sustainable development and make profits. It represents around 11.65% of global weights. The other two sub-risks over 10% global weights are the "renewable energy policy changes" risk and the "tower collapses, fire and the blade break damage to the third parties or neighbours" risk. The reduction of financial subsidies and taxation benefits should be the trend of the Chinese wind energy market. Therefore, they rank fourth and fifth among all risks, which account for 6.17% and 5.75% respectively. Four risks at the top five ones are political risks, which emphasizes the significance of the political issues in the distributed wind project. This article possesses three contributions: First, through literature review and experts interview, the risk factors checklist of distributed wind park in China is provided; Second, this study has provided a quantitative risk assessment of distributed wind farm through the implementation of the multiple criteria decision-making methods (MCDM); Finally, future research topics of distributed wind power has also been identified. Dallas (2008) discusses that the purpose of risk management is to deliver the maximum value to the project. It is impossible to get the highest benefits by avoiding all risks in the project. The primary task of the project manager is to design a structured and disciplined scheme for the team to response and control risks efficiently.

Wind energy as renewable and clean energy should be an indispensable piece for the future energy structure in China. Some factors hinder the distributed wind power deployment such as political issues, environmental pollutions, safety and security problems, limitation of technology, etc. However, the booming development of distributed wind energy will be a future trend under the severe threatening of traditional energy depletion and environmental issues. There are still several points that can be improved such as another more precise method employed for the assessment of the risk impacts, the influence of technological development, other distributed wind power problems and so on.

This research has covered and assessed most of the risk factors in the distributed wind power system in China. Political and regulatory risks will remain affecting investors if policymakers cannot publish reasonable policies and regulations. The application of new technology will enhance safety and maintain the stability of the distributed generation system.

The interviewed company produced the new generation wind turbine that installs decades of sensors on the wind turbine, blades, and towers to monitor operating status around the clock. The sensors on the wind blades can detect the degree of damage to prevent loss of the company and surrounding people due to blade breakage. The new wind speed detector enables the wind turbine to know the wind speed in advance to improve the efficiency of power generation.

7.2 Future Work

7.2.1 Risk Treatment Plans

The risk treatment stage of the risk management process was limited to the discussion of three actions (including risk mitigation, risk prevention, and risk transfer) for this study. The development of a well-qualified pool of maintenance contractors in a competitive market is a helpful recommendation for Technical risks. The better performance of the maintenance contractors reduces the consequence of the risk R7, R14, R21 and the probability (-50%) to have the risk no. 20. Omitaomu et al. (2012) introduce a new approach based on geographical information systems (GIS) to develop decision making on renewable energy resources. An approach combined GIS-MCDM employs to select the optimal location for the distributed wind park through wind speed analysis and simulating the effectiveness and yield of the wind parks in different places.

7.2.2 Monitoring and Reviews System

An accomplished risk management process includes risk monitoring and feedback. The team needs to examine the outcome of approved risk treatment and document in a table including the risk events, risk treatment methods, progresses and compliance reporting. When employing the risk treatment actions (including modification of schedule, the means of work or contract terms) to mitigate risk impact, the project may appear a new risk. The emerging risk needs to be logged immediately. Then, the project team performs risk reassessment to prioritise the updated risk factors. Therefore, the risk management process in the distributed wind power project has formed a closed loop. The optimum solutions for the risks that only occurs in the distributed wind power system will discuss in the future study.

Acknowledgement

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