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Research Article

Risk Assessment and Analysis of Biomass Energy Engineering Project Management under the Concept of Sustainable Development

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Energy is the foundation of national economic and social development. With the rapid development of the global economy, energy shortage has become an urgent problem for countries to solve, and it has gradually become a bottleneck restricting Chinese current and future development. The ecological environment pollution is caused by the development and utilization of traditional energy. The problem is getting worse. How to develop and utilize clean energy while improving the environment and reducing pollution has become one of the important issues that countries need to solve urgently. Biomass energy (referred to as biomass energy) is widely distributed, renewable, and easy-to-use green energy, and its effective development and utilization is of great strategic significance for driving the development of emerging energy industries, preventing global warming, and promoting the establishment of a circular society. Therefore, it is of great scientific, economic, and social significance to develop and utilize biomass energy efficiently, relieve the pressure of energy demand, improve the environment of the ecosystem, and ensure regional economic development. For this reason, this paper designs energy complementation and bidirectional coupling between gas-electric systems, highly nonlinear operation characteristics of gas network components, gas network pipeline leakage failure modes, and multiple failure modes of compressor stations and carries out probabilistic risk assessment of gas-electricity integrated energy system.

1. Introduction

In the context of the rapid development of the global economy, the demand for energy is increasing day by day [1]. At the same time, most countries still use fossil fuels as the main energy utilization method and face many serious problems such as environmental pollution, shortage of energy resources, and climate change [2]. Based on different economic development goals and resource conditions, countries around the world are actively developing and utilizing renewable energy sources such as wind energy, solar energy, and biofuels [3]. Among the three renewable energies, biomass energy is the only material energy. It exists on the earth in the form of agricultural, forestry and aquatic resources, organic wastes, domestic garbage, and so on. It has many advantages such as large storage capacity, strong storage performance, and high substitutability. At present, the research and development of biomass energy technology has become one of the major hot topics in the world. Many countries have formulated corresponding development and research plans, such as Japan's Sunshine Plan, India's Green Energy Project, the United States' energy farms, and Brazil's alcohol energy plan. The development of renewable energy can realize sustainable development of energy utilization, promote economic development, and relieve environmental pressure, which is an important direction of energy development [4]. Chinese energy utilization structure is relatively simple. For a long time, coal and other fossil fuels are the main sources, which limits the sustainable development of Chinese society and economy [5]. At present, realizing the sustainable development of energy planning and utilization and promoting the sustainable development of society and economy are one of Chinese major strategic tasks [6].

In my country, the total reserves of energy resources are huge, and there are abundant energy types [7]. The abundance of energy and mineral resources in my country is about 60% higher than the global average abundance, making it one of the countries with the highest abundance of energy and mineral resources in the world [8]. However, my country has a large population, the per capita possession of energy resources is small, and the energy structure is unreasonable and unevenly distributed [9]. Chinese per capita energy resources are very limited, only equal to 1/2 of the world's average level; in terms of distribution area, North China and Northeast China have about 80% of mineral resources, and Southwest and Northwest regions have 70% of the country's hydropower resources [10]. Only 20% of the country's total energy resources are concentrated in densely populated areas such as East China, Central China, and South China [11]. In addition, the utilization rate of fossil fuels in my country is very high, and the combustion of fossil fuels will cause serious air pollution and environmental problems [12]. The burning of coal in fossil fuels is responsible for 90% of sulfur dioxide, 70% of soot, and 85% of carbon dioxide pollution in the atmosphere, while causing environmental problems such as atmospheric warming, sea level rise, and acid rain. Scientific research shows that if other nonfossil fuel combustion methods are not adopted, by 2050, Chinese sulfur dioxide and carbon dioxide emissions will double compared to now [13]. The hard facts mean that there is an urgent need to solve the research and application of renewable and clean energy [14]. Therefore, the direction of Chinese power planning needs to be adjusted according to the characteristics of energy resources and the pressure of energy conservation and emission reduction, that is, focusing on optimizing the development of thermal power, developing hydropower in an orderly manner, actively promoting the construction of nuclear power, and vigorously developing renewable energy [15]. The Chinese government has realized the importance of renewable energy, including biomass energy, in the country's future energy system and formulated a series of laws and regulations to promote and ensure the development of the renewable energy industry. In the Renewable Energy Law of the People's Republic of China, which was officially promulgated and implemented on June 1, 2006, the status confirmation, price guarantee, tax preference, etc. of renewable energy have been written into the law, and the nine supporting regulations detail the protection of green energy into power generation management, price sharing, technical specifications, etc. According to the application field, construction scale, technical characteristics, and development status of various renewable energies, it is estimated that the investment required to achieve the 2020 tasks set out in the plan will be up to 2 trillion yuan.

In order to adjust the country's energy structure, reduce environmental pressure, and enhance the sustainable development capacity of society and economy, it is of great significance to accelerate the in-depth research and technological innovation of renewable energy, and it also has an important ability to assess the country's comprehensive national strength and scientific and technological development level [16]. However, in the process of renewable energy development and investment, there are many uncertainties [17]. First of all, in terms of incentive mechanism, considering that renewable energy has greater technical risks, governments around the world have introduced policy incentive systems including laws and economics to encourage renewable energy investment entities [18]. The driving effect of energy is not the same. The uncertainty of this incentive mechanism will cause potential changes in the investment motivation of investment entities, thereby affecting the scale of renewable energy investment, regional selection, and economic benefits; second, in terms of transmission constraints, considering that large-scale renewable energy generation is often far away from the load center and requires long-distance transmission, transmission system planning and capacity expansion and upgrading have become increasingly important, and the uncertainty of such transmission constraints will have an important impact on renewable energy investment planning. Third, in terms of power consumption level, demand-side response resources have become an important resource [19–21]. When planning renewable energy investment, in addition to supply-side resources and transmission constraints, it is also necessary to consider cost-effective demand-side response [22–24]. Due to the universality and dispersion of users, there are great uncertainties in the demand side resources, which may affect the optimal scale of renewable energy investment. These uncertainties may have a negative impact on renewable energy investors. Therefore, before entering the industry, each investor needs to fully understand the development status of renewable energy, identify the risks of renewable energy, and take corresponding risk response measures.

To sum up, in the process of vigorously promoting the development of renewable energy, the continuous uncertainty of incentive mechanism, power transmission level, and power consumption level will increase the capital cost of renewable energy investment enterprises and affect the investment enterprises to a certain extent. Therefore, it is particularly necessary to study renewable energy investment and its risk assessment under uncertain conditions.

The objectives of this study are first, to construct the theoretical framework of biomass energy risk assessment in China. Through the analysis of the current domestic and foreign related risk and risk management research, combined with the understanding of the characteristics of biomass energy itself and the obstacles to its development and utilization, a series of basic problems of risk management, such as biomass energy risk identification, risk assessment, and risk prevention, were studied in depth and systematically, forming a relatively complete basic theoretical framework of biomass energy risk management. Second, establish a systematic and perfect biomass energy risk management and prevention system. Using the evaluation results and combining the risk management and prevention measures in the process of biomass energy industry development in various countries in the world, the paper further discusses China's biomass energy risk management mode and prevention measures and puts forward countermeasures and suggestions that can reduce the development risk of China's biomass energy industry, in order to provide theoretical reference for relevant management decision-making departments.

2. Materials and Methods

2.1. Biomass Energy. Biomass refers to various organisms produced by photosynthesis using the atmosphere, water, land, etc., that is, all living and growing organic substances are generally called biomass. It includes plants, animals, and microorganisms. Biomass includes all plants, microorganisms, animals that feed on plants and microorganisms, and their wastes. There are some representative biomass such as crops, crop waste, wood, wood waste and animal manure. Biomass energy has the characteristics of renewability, low pollution, and wide distribution. The energy of biomass comes from the sun, so biomass energy is a kind of solar energy. Biomass is the most important absorber and storage of solar energy. Biomass can enrich solar energy through photosynthesis and store it in organic matter. These energies are the source and basis of energy for human development. The main sources of biomass energy are fuelwood, livestock manure, sugar crops, municipal waste and sewage, aquatic plants, etc. (see Figure 1). Since biomass is derived from CO2 in the air, and it is burned to generate CO2, it will not increase the content of CO2 in the air, so biomass has the characteristics of "carbon neutrality" and is cleaner than mineral energy. The utilization of biomass energy mainly includes three ways: direct combustion, thermochemical conversion, and biochemical conversion. The main approaches are (1) direct combustion technology includes household stove combustion technology, boiler combustion technology, biomass and coal mixed combustion technology, and related compression molding and baking technology. (2) Biotransformation technologies include small household biogas digesters, large, and medium-sized anaerobic digestion. (3) Thermochemical conversion technologies include biomass gasification, dry distillation, and rapid pyrolysis liquefaction technologies. (4) Liquefaction technology includes the technology of refining vegetable oil, preparing ethanol, methanol, and other technologies. (5) Organic waste energy treatment technology.

Livestock and poultry waste is a general term for livestock and poultry excrement, which is the transformation form of other forms of biomass (mainly grain, crop straw and pasture, etc.), including the excrement, urine, and the mixture of livestock and poultry excrement and bedding. As an important biomass energy, livestock manure is mainly used as fermentation raw material for biogas, except for a small amount of direct combustion in pastoral areas. The main livestock in China is chickens, pigs, and cattle. According to the breeds, body weights, and excretion of feces and other factors, the amount of manure resources can be estimated. According to calculations, the total amount of livestock manure resources in my country is currently about 850 million tons, equivalent to more than 78.4 million tons of standard coal, of which cow manure is 578 million tons, equivalent to 48.9 million tons of standard coal, and pig manure is 259 million tons, equivalent to 22.3 million tons of standard coal. 14 million tons of chicken manure is equivalent to 7.17 million tons of standard coal.

Among manure resources, manure from large and medium-sized farms is more convenient for centralized development and large-scale utilization. At present, there are more than 6,000 large and medium-sized cattle, pig, and chicken farms in my country, which discharge more than 800,000 tons of manure and flushing sewage every day. Although China has a huge potential for the development and utilization of biomass resources, and there is a huge potential demand for biomass energy due to the national energy gap, due to a series of risk factors such as low energy conversion efficiency, high production costs, inadequate public awareness of consumption, and inadequate incentive policies and management systems, these potential needs cannot be translated into actual needs, making the consumption of biomass energy in China far less than its demand.

Based on the research on the status of biomass energy utilization, combined with resource endowment, ecological environment status, and scientific and technological progress level, the development potential of biomass energy can be estimated. At present, a large number of researches are to explore the utilization potential of biomass energy from the perspective of the whole energy. The global biomass contribution potential in 2050 is 100×1018 to 450×1018 joules per year. Besides, there are also a lot of studies on the biomass potential at regional and national scales: Latin America, Africa, and Southeast Asia, respectively 64.78×2050 1018, 43.6×1018, and 23.55×1018 joules/year, 26.3×1018 joules/year for the EU, 15.89×1018 (2050), 2.1×1018 and $0.93 \sim 4.56\,(2010) \times 1018$ for the United States. The development of biomass energy is restricted by social, economic, resource endowment, ecological environment, and other conditions, so the future development speed and potential of biomass energy at different regional scales have great uncertainty. Material energy will play an important role in the future energy system. The Biomass Handbook published by the Japan Energy Association in 2003 introduced the basic knowledge of biomass resource development and utilization and related technologies in detail, which became a guidebook for biomass energy utilization.

2.2. Comprehensive Evaluation Theory. Comprehensive evaluation refers to the method of comprehensive evaluation of a system based on multiple related factors and multiple related indicators according to the characteristics of a system affected by multiple factors at the same time. Generally, a comprehensive evaluation problem is composed of five basic elements: evaluation object, evaluation index, weight coefficient, comprehensive evaluation model, and evaluator. At present, there are many comprehensive evaluation methods: TOPSIS method, analytic hierarchy process, fuzzy comprehensive evaluation method, grey system method, etc. The application of comprehensive evaluation methods to model research began in the 1890s and was extended to natural

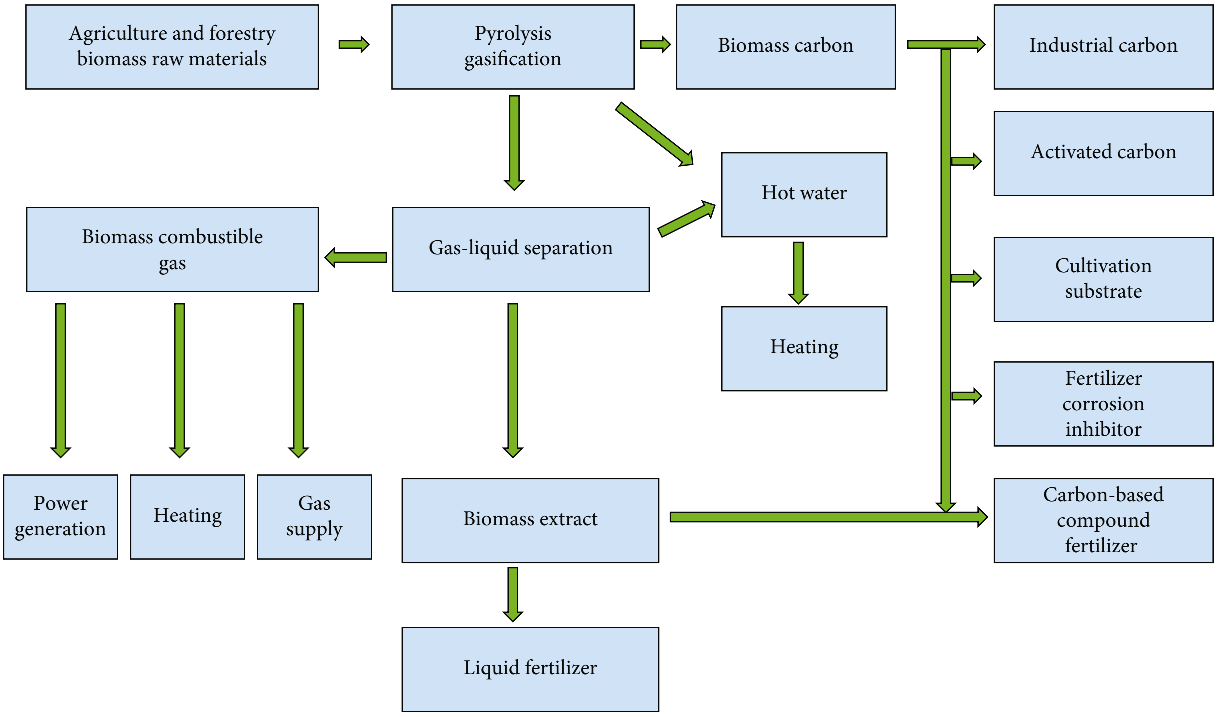

Figure 1: Biomass energy recycling diagram.

resources and environmental research through input-output models, including Ayres and Kneese in 1969, Leontief in 1977, Forsund in 1985, Lee in 1982, and Perrings in 1987; most scholars mainly study how resources and pollutants affect from one industry to another. In many complex economic models, inputs of natural resources and environmental substances are in physical units, while economic development variables are in monetary units.

The general comprehensive evaluation model should include how energy and environmental policies affect macro social and economic development and the output level of economic development, how the impact of energy and environmental policies on economy is distributed among different sectors of economic development, and how to improve policies. Turner's research on the general comprehensive evaluation model in 2000 shows that the composite system model mainly uses the data information in the input-output table to predict the resource input of various industries, the generation of pollutants, and the change of economic activities under various assumptions and scenarios.

The management of engineering project risk is mainly carried out by carrying out the risk identification of the engineering project, the risk analysis and measurement of the engineering project, and the evaluation of the risk of the engineering project. And on this basis, make appropriate use to deal with various construction risks in the project, improve the deficiencies in the ordinary project management methods in the construction, and deal with the construction risks in the project in a timely and effective manner. Overcome sudden risk events and eliminate losses caused by engineering risks. The risks of engineering projects are often related to various engineering changes. By controlling the risk-inducing factors, the purpose of reducing engineering risks can be achieved, and positive countermeasures can be taken to expand the positive factors and reduce the negative factors, so as to achieve the goal of reducing the risk of engineering projects.

The project risk assessment is to identify, estimate, and evaluate the risks that may be encountered by the project, so as to reasonably use multiple methods, technologies, and means to effectively control the risks involved in the project activities, take initiatives, create conditions, maximize the beneficial results of risk events, properly handle the adverse consequences caused by risk accidents, and ensure the safe and reliable realization of the overall goal of the project with the least cost.

It is necessary to link the risk management objectives of the project with the probability of occurrence of risk events of the project. During project construction, it is necessary to prevent risks in advance, conduct extensive investigation, prepare for risk prevention, reduce the probability of potential risks, and reduce losses in these aspects. Achieving this goal usually requires a strategy that employs multiple risk approaches, which can be achieved through risk monitoring. If the risks of the project are not analyzed and identified in advance, the project manager will be worried about the risks that may occur in the project at any time. Risk anxiety will not only disperse and consume the time and energy of the construction manager but also increase the difficulty of quantifying the project risk management. It also needs to meet the additional external obligations of the project, such as certain behaviours strictly prohibited by the government and mandated by law. At present, the investors of biomass energy projects in China are not only faced with common risk factors in construction projects, such as the price and supply of building materials, changes in on-site construction conditions, delays in design data, errors in bidding and quotation, and interference from the public and other social institutions, but also faced with more uncertain risk environments, mainly including immature equipment and technology. There is no formed and economically accounted fuel collection and storage mode. The development system of biomass industry is not perfect, and the social credit system and legal and regulatory system are not perfect.

This study considers that the primary task of regional risk assessment of biomass energy is the assessment of the basic potential risk of regional biomass energy, which represents the maximum development potential of regional biomass energy when the conditions of policy, technology, market, and cognition are greatly met. Second, after the assessment of the basic potential of biomass resources, that is, after the regional resource potential risk is determined, gradually consider and add other regional risk components. In principle, the overall risk of regional biomass energy development and utilization will increase with each additional risk factor. Each risk factor has different effects on the risk of different regions and will also have a certain degree of influence on each other. When all risk factors are not taken into account, the final assessment result is the overall risk of regional biomass energy industry development.

2.3. Sustainable Development Theory. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs. The ultimate concern of sustainable development is the balanced development of ecology, society, and economy. It first advocates the progress and development of human society from the perspective of environmental protection. Its main content involves five elements of population, resources, environment, economy, and social development, including the needs of present and future generations, national sovereignty and international equity, natural resources and ecological carrying capacity, the combination of environment and development, etc., involve sustainable development of ecology, resources and environment, sustainable social development, and sustainable economic development. Sustainable development adheres to the principles of fairness, continuity, integrity, and focus, and its main contents include sustainable utilization of resources, environmental protection, clean production, sustainable consumption, public participation, and scientific and technological progress. The factors of sustainable development are the unity of opposites, which are interrelated, restrained, and influenced by each other.

Sustainable development requires that economic construction and social development should be coordinated with the natural carrying capacity. At the same time of development, we must protect and improve the earth's ecological environment, ensure the sustainable use of natural resources and environmental costs, and control human development within the earth's carrying capacity. Therefore, sustainable development emphasizes that development is limited, and there is no sustainable development without restrictions. Ecological sustainable development also emphasizes environmental protection, but is different from the previous practice of opposing environmental protection and social development. Sustainable development requires that environmental problems be fundamentally solved from the source of human development by changing the development model.

3. Results and Discussion

3.1. Multistage Optimization Model of Renewable Energy Investment. In this model, for each renewable energy power plant project $j = 1, \cdots, n$, the investment decision-making stage takes years as a cycle, $t = 1, \cdots, T$, denoted by the subscript t. The power generation amount of the corresponding power plant and the short-term market electricity price are in monthly units, which are represented by the subscript τ , where the monthly power generation amount of the power plant and the node price in the short-term market are random and are represented by E and P, respectively. $X0$ is the 0-1 decision variable of investment. If investment activities are carried out, investors also need to decide the share A purchased in the investment project y and the electricity sales Dqt in the long-term contract of the project this year, in which the qt contract electricity is the proportion of the available capacity. The unit is MW. f is the electricity price in the long-term contract. It is assumed in this paper that each investor is allowed to make a partial investment in a power plant. Because in the actual large-scale infrastructure investment process, the project may be jointly invested by multiple investment entities, and a single investment entity only undertakes part of the investment tasks.

Based on the above assumptions, the decision variables in this problem are xr, and qr. Let $y = (ql, rt)En + 1.t = 1, \cdots, T$, the multistage stochastic programming investment model for renewable energy portfolio optimization is as follows:

$$\max_{x,y_t} E\left[\sum_{i=1}^{T-1}\left(a_1^\top y_t + \sum_{i=1+b}^{i+b+l-1} c_i^\top y_t (1+\rho_c)^{1-i}\right) x_i (1+\rho_c)^{1-i}\right]. \tag{1}$$

In the formula,

$$a_t := \left(\varsigma (1+\rho_c)^{-b} D f_t \sum_{\tau=12(t-1)+1}^{\tau=12t} h_\tau, -v\right), \tag{2}$$

$$c_t := \left(\sum_{\tau=12(t-1)+1}^{\tau=12t} - D P_\tau h_\tau, \sum_{\tau=12(t-1)+1}^{\tau=12t} - P_\tau h_\tau E_\tau\right). \tag{3}$$

The model builds the objective function with the maximum project investment benefit, as shown in formula (3), which mainly includes two parts, the first part is the fixed investment cost and income of the project, that is, the initial investment cost of the project and the long-term contract electricity sales revenue; the second part is the variable cost and income of the project, mainly the purchase and sale of electricity by the project target power plant in the short-term electricity market benefit. Among them, atc' represents the net present value coefficient of the fixed investment cost of the project and the short-term electricity market participation income coefficient. Formulas (3)–(7) represent the upper limit constraint of the long-term electricity contract sold capacity Dqt (contracted capacity x sales ratio), which cannot exceed the total investment capacity of renewable energy projects. P is the capacity factor of the renewable energy project j; $D = dr + \cdots + d\}$ is the vector (d). $ynaV = V$ 1, $V2, \cdots, Vn$) represents the investment cost of each project, h is the number of hours in a month, and apricot is the annual net present value discounted to the initial year of project investment. The construction period of the project is month b, and the discount rate is pQ.

Once the contract is signed, the short-term electricity market participation benefit of a power plant can be expressed as

$$\sum_{\tau=12(t-1)+1}^{\tau=12t} \left[P_\tau h_\tau \left(r_t E_\tau^\top - Dq_t \right) \right]. \tag{4}$$

Therefore, the vector expression situation of the short-term electricity market revenue coefficient of project investment can be deduced, as shown in (4). Because the monthly power generation of renewable energy and the short-term electricity market transaction price are random variables, the above investment optimization model is a multistage stochastic programming model, and the investor's investment optimization goal is to maximize the expected return of the project.

4. Model Refactoring

Since the above models (1)–(4) are nonlinear, the above problems are difficult to solve by conventional algorithms. This part will reconstruct the above model, assuming that the life cycle of the project is $T + l - 1$, and ignore the project investment decision cycle.

First of all, the investment decision can be expressed as: when the $0 - 1$ variable $z\, t = 1, \cdots, \mathrm{To}\, z\} - 1$ is introduced, it means that in the time period t, on the contrary, $z = 0$. In order to simplify the model, the project construction period is one year, or the above stochastic optimization model is carried out before the period t can be expressed as

$$\max_{x_t, y_t, z_t} \mathbb{E} \left[\sum_{t=1}^{T-1} \left(a_t^\top (y_t - y_{t-1}) + c_t^\top y_{t-1} \right) (1 + \rho_c)^{1-t} + \sum_{t=T}^{T+t-1} c_t^\top y_T (1 + \rho_c)^{1-t} \right], \tag{5}$$

$$z_t = x_t + z_{t-1}. \tag{6}$$

Formula (5) is the project investment decision constraint, that is, if $zt = 1$, because $x^{'}$ and z are both -1 variable, then, there must be $xt = 0$, and $zt = 1$. The formula can guarantee that for a certain item, if a certain period x is taken, once it takes 1, then, the subsequent period $x^{'}$ is all zero. Formula (6) means that if the project decides to invest in a certain period of time, it needs to ensure that $yt < 1$ (i.e., $qt < 1$ and rte 1), but before the investment is completed, $y = 0$. Therefore, it can be obtained that for all t, there are $xrY = y = yt - 1$. In the last year of the planning year, investors will no longer invest in new renewable energy projects, so $xT = 0$ in (6). Substitute $xtYt = yt - yt - \}$ into the original model objective function formula (5), the nonlinear terms in the original model will be linearized, so after the basic model is reconstructed, the original model becomes a linear multistage stochastic programming model.

Due to the uncertainty of power generation and short-term market electricity price, the above optimization (maximization) is carried out under the strategy that satisfies the feasibility constraint (unexpected), that is, the decision variables $(x, y, zi) = (x(su), y\,(\xi q), z(su))\; t = 1 \cdots,$ T are a function of the historical records of data processing $\xi u = (\xi u \cdots \xi u)$ in

$$\xi_t \coloneqq \left(P_{12(T-1)+1}, \cdots, P_{12t}, E_{12(T-1)+1}, \cdots, E_{12t} \right), \tag{7}$$

$$\xi_T \coloneqq \left(P_{12(T-1)+1}, \cdots, P_{12(T+1-1)}, E_{12(T-1)+1}, \cdots, E_{12(T+l-1)} \right). \tag{8}$$

This section proposes a risk-neutral planning model. When considering the scenario of risk aversion, the expectation operator in (8) can be replaced by an objective function that is easy to choose. Given the uncertainty of these investments, often investors come up with some kind of risk aversion.

4.1. Model Solution. Due to the large number of possible scenarios, numerical methods based on scenario enumeration will cause computational dimensionality disaster. Therefore, in this section, the abovementioned planning problem will be solved by the stochastic dual dynamic programming algorithm (SDDP). To solve the above problem through SDDP, the first step is to discretize the continuous random process in the objective function. This paper will use the Monte Carlo algorithm to sample the above random process. That is, by extracting scenes, the "expected cost" function in the SDDP problem is approximated by the sample average approximation (sample average approximation SAA) method. Since the data sequence is required to be uncorrelated between stages in the stochastic-dual dynamic programming algorithm, the expected value of "expected cost" does not depend on the input data sequence required by the model. If the input random data sequence is correlated between stages, then, the linear approximation of the "expected cost" function in SDDP will not guarantee the convexity of the optimization model.

In order to better describe the above stochastic process, this section will reformulate the above problem through dynamic programming. At $t = T$ (at this time $xT = 0$), the investor's decision-making model at this stage can be represented by the following form:

$$\max_{x_T, y_T, z_T} \sum_{t=T}^{T+l-1} c_t^\top y_T (1 + \rho_c)^{T-t}, \tag{9}$$

$$y_T \le y_{T-1} + 1 - z_{T-1}. \tag{10}$$

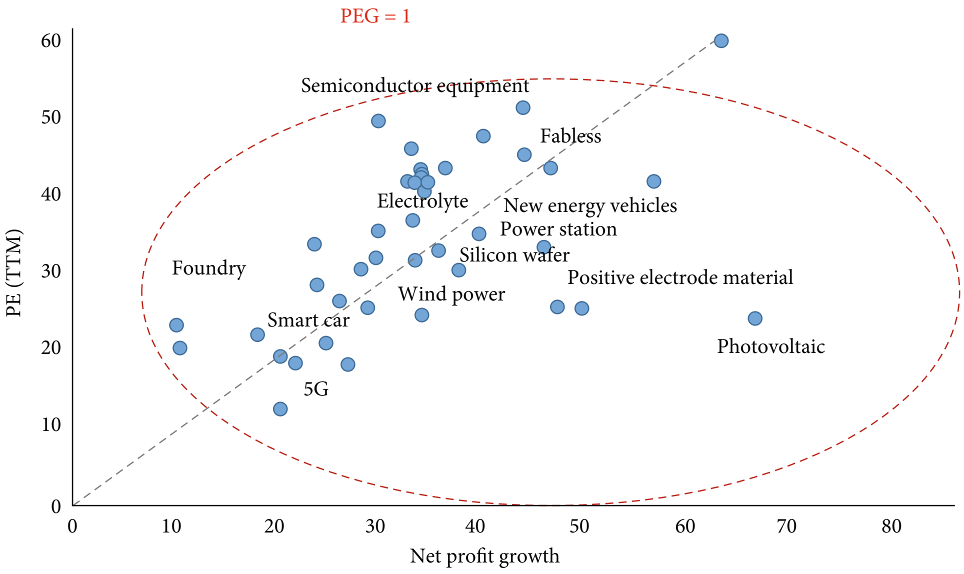

Figure 2: Risk and return in independent scenarios for different X values.

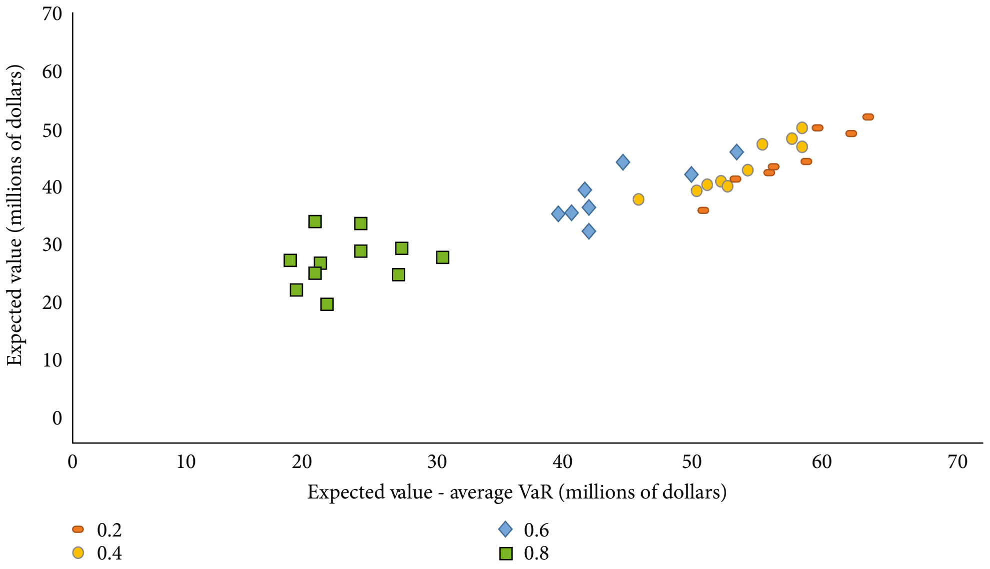

Figure 3: Efficient frontier for dependent cases.

Since the data process is assumed to be a Markov process, the "expected cost" function $O(Y-Z)$ and its expected value function $Q+(Y,Z5)$ only depend on ξu rather than the entire time period. When ξ is a special case of stage independence, the conditional expectation in (3-20) can be replaced by the corresponding unconditional expectation, and the corresponding expectation function $Ot+1(vz))$ does not depend on random input data sequence.

The optimal decision model of each stage is constructed in reverse order, and the optimal value of the corresponding "expected cost" function can be obtained for any one. The specific expression form is shown in formula (11):

$$\max_{x_T,y_T,\mathbf{z}_T} a_t^{\top}(y_t-y_{t-1})+c_t^{\top}y_{t-1}+\mathcal{Q}_{t+1}(y_t,z_t,\xi_t)(1+\rho_c)^{-1}, \tag{11}$$

$$z_t=x_t+z_{t-1}. \tag{12}$$

Finally, for the first stage, that is, the initial stage of investment $z0=0$, the investor's decision-making model can be expressed as

$$\max_{x_1,y_1,z_1} a_1^{\mathrm{T}}y_1+\mathbb{E}[\mathrm{Q}_2(\mathrm{y}_1,\mathrm{z}_1,\xi_1)](1+\rho_c)^{-1}, \tag{13}$$

$$z_1=x_1. \tag{14}$$

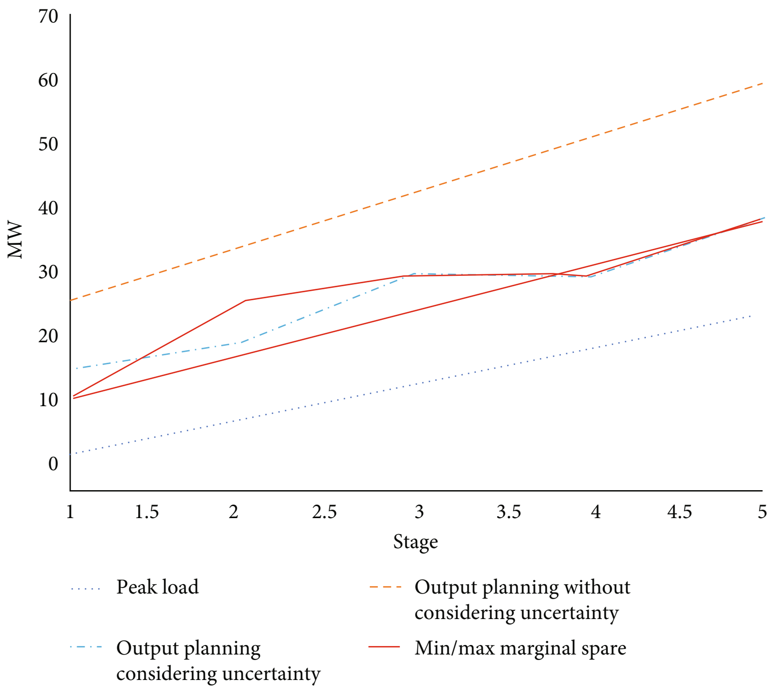

Figure 4: Comparison of power reduction results of A5 units in scenario 1 and scenario 2 under the condition of 10% reduction of wind farms.

Therefore, any autoregressive process has its own natural conditions and the amount of natural water in the secondary market. For a given power plant, the monthly capacity factor furnace T (wind or hydro) is modeled as

$$W_\tau^j = \sum_{i=1}^{12} \gamma_i^j \delta_{i\tau} + \sum_{i=1}^{p} \phi_i^j W_{\tau-i}^j + \sum_{i=1}^{q} \sum_{k=1}^{4} \eta_{ik}^j I_{\tau-i}^k + \varepsilon_\tau^j. \qquad (15)$$

5. Experimental Results and Analysis

5.1. Optimization Results considering Risk Aversion. In a risk-neutral approach, the paper uses an appropriate discount rate to discount the actual measured cash flows and adjusts accordingly. In the process of consistent measurement of risk, $R[Z]$ corresponds to certainty equivalence, so it is necessary to select the risk-free interest rate as the pricing framework of real options to avoid the risk of double calculation.

Figure 2 shows the out-of-sample expected return and expected return minus the average value at risk of different samples at some different levels of risk aversion. It is found that the relationship between the expected risk aversion and the uncertainty of the strategy does not occur.

Tests were repeated with correlation methods, correlating in-sample and out-of-sample results. The convergence of the forward simulation cannot be assessed because it is not a lower bounded risk in the risk aversion case method. And change the meaning value to repeat the above experiment and sampling.

As can be seen in Figure 3, an efficient frontier is obtained by sampling from different problems. A strategy that best reflects risk aversion can be selected from the set of Pareto optimal solutions. The analysis of the results shows that the higher the investor's requirements for the degree of risk aversion, the greater the number of forward contracts signed. It shows that for renewable energy investment, the signing of long-term contracts can hedge the uncertainty faced by renewable energy investment to a certain extent.

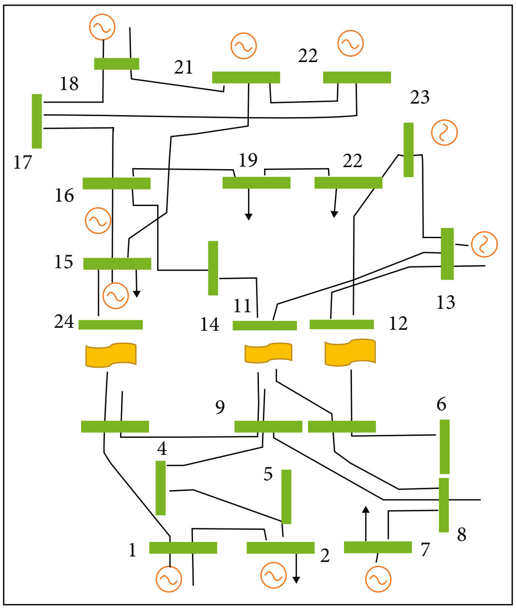

Figure 5: IEEE 24 node test system.

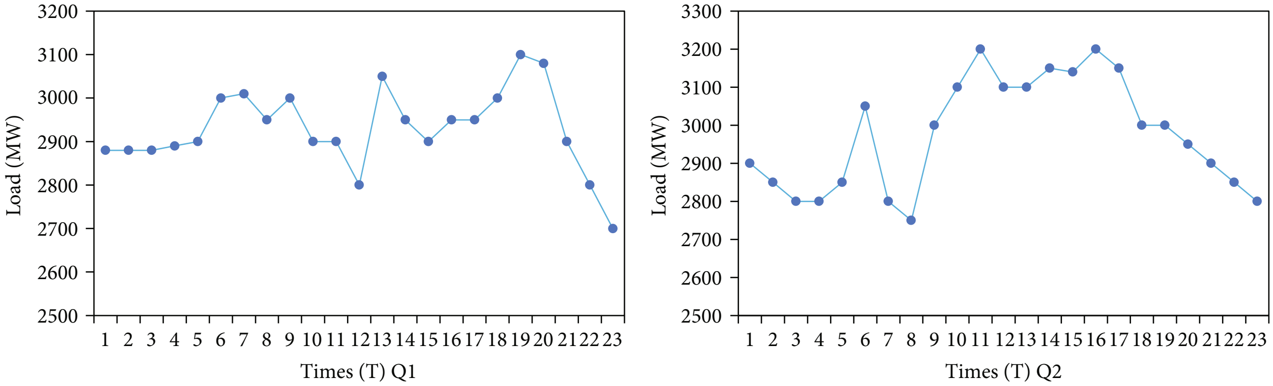

Figure 6: Typical daily load curve in different quarters.

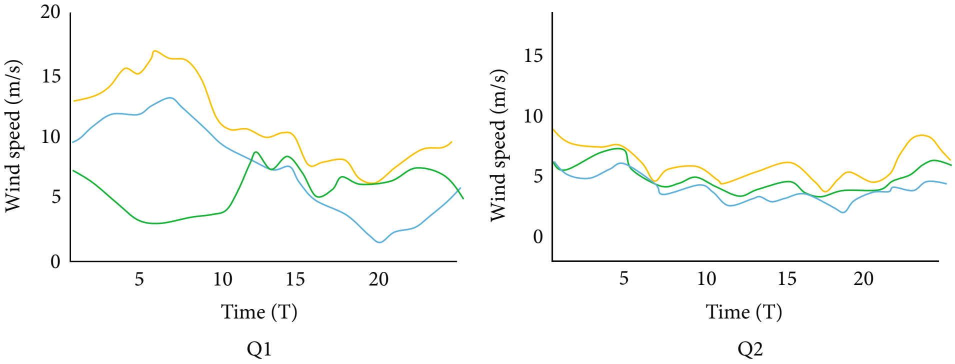

Figure 7: Variation of wind speed at high, medium, and low levels under different load levels.

5.2. Analysis of Examples. This section mainly analyzes the impact of wind farm uncertainty in planning, and the scenarios are arranged as follows: uncertainty is considered in the planning model of scenario 1; uncertainty is not considered in the planning model of scenario 2. The marginal reserves of the two scenarios are shown in Figure 4. Scenario 1 is more stable than scenario 2. The marginal reserve of scenario 2 is within the range of the marginal reserve of scenario 1, and there is no suitable marginal effect. The marginal reserve of scenario 1 is in an acceptable interval with a suitable marginal effect. As a result, this plan is more flexible and helps agencies maximize profits with minimal risk.

Figure 4 shows the simulation results of scenario 1. It can be seen that power generation companies and power supply companies install different generator sets and transmission lines to maximize profits. Among them, the generator set with high investment cost has been installed in previous years.

Aiming at the above model, this chapter simulates in the IEEE 24 node test system and solves the model through CPLEX. The IEEE 24 node system includes 24 busbars, 11 conventional generator nodes, and 17 load nodes. Its basic structure is shown in Figure 5.

In this example, the daily load curve in the IEEE-24 node system is modified, and the model is simulated based on the daily load curve and wind speed data of a certain place in North China. The data for different loads and wind speed levels are shown in Figure 6.

In the IEEE24 node system, there are traditional generator sets at nodes 1, 2, 7, 13, 15, 16, 18, 21, 22, and 23, and the output interval and quotation interval are shown in Figure 7. The reference bus in the test system is 14 nodes, that is, ref = 14. Wind turbines can be connected at nodes 7, 13, 17, and 22. The minimum unit of access is 50 MW, the maximum capacity that can be connected is 600, 300, 300, and 300, and the unit is MW. The total investment cap for wind power is 1.5 × 10$. The above model is solved in CPLEX, the result is that the wind power investment benefit is the greatest when all nodes are installed according to the maximum capacity, and the expected benefit is 89.562 × 1066.

When the upper limit of wind power investment becomes 10 × 10$, the optimal wind power installation strategy obtained is that the maximum capacity is connected to the 7th node, that is, 600 MW, the 13th node is connected to 50 MW wind power, the 17th node is connected to 50 MW, and the 22nd node is connected to the maximum capacity. The capacity of wind power is 300 MW, which is expected to be 61.166 × 106$. In this scenario, if only the typical daily load and wind speed data in the third quarter and the fourth quarter are used for calculation into the model, it can be found that when only the third quarter data is used, the installed capacity at node 7 is 600 MW, and the installed capacity at node 22 is 300 MW, 100 MW at nodes 13 and 17; when calculated using the typical daily load and wind speed data in the fourth quarter, the installed capacity at node 7 is 300 MW, the installed capacity at node 22 is 300 MW, the installed capacity at node 13 is 50 MW, and the installed capacity at node 17 is 0 MW. When using only the third quarter load and wind speed data, the wind power investment income is 76.746×1066, and when using the fourth quarter load and wind power data, the wind power investment income is $67.857 \times 10\$$. Because the load peak-to-valley difference in the third quarter is small, and the antipeak shaving characteristics of wind power are not as obvious as those in the fourth quarter, the on-grid electricity of wind power is more than when the load and wind speed data in the fourth quarter are used, and the wind power investment can also be better earnings.

6. Conclusion

In the context of global climate change, increasing dependence on fossil energy imports, and increasing electricity demand, the demand for renewable energy in various countries has surged, which will inevitably prompt governments to encourage enterprises to invest in renewable energy to achieve sustainable development. However, there are uncertainties in many aspects of renewable energy investment, especially in the future electricity market environment, renewable energy investment will face more uncertainty. Through the research on renewable energy investment and its risk assessment under uncertain conditions, this paper provides a corresponding strategy for renewable energy investors to optimize investment and proposes a benefit evaluation index system for renewable energy investment projects. Provide a basis for rationally developing renewable energy, ensuring national energy security, and achieving energy conservation and emission reduction goals.

In the risk study, the vulnerability of the insured is also an important factor leading to risk losses. Based on the content of this study, we can continue to establish a comprehensive insurance system that is divided into social, economic, and environmental aspects; establish a risk identification, classification standard system, and evaluation index system for different insured objects; build a risk evaluation model; propose policy recommendations on key technologies for risk prevention; and form a technical system for identification, evaluation, and prevention of biomass energy risks in line with China's national conditions to provide technical support for government management, enterprise production, and the public to prevent biomass energy risks. In a word, there is still a lot of research space and development potential for biomass energy risk assessment and management in China, which needs to be further studied and discussed, so as to build a complete theoretical system and application system of biomass energy risk management, achieve effective management of biomass energy risk, and also provide reference for risk management in other forms of renewable energy.

Data Availability

The figures used to support the findings of this study are included in the article.

Conflicts of Interest

The author declares no conflicts of interest.

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