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Distributed photovoltaic index insurance premium prediction method based on ARIMA model

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Abstract: Photovoltaic power generation is an important field of the current new energy development, and distributed photovoltaic mode has gradually become an important trend in the development of the photovoltaic industry, for the distributed photovoltaic industry in China's domestic development status, there is an urgent need for a new kind of insurance products, to support photovoltaic enterprises to promote the development of the industry. ARIMA distributed PV and index insurance are reviewed. After researching and synthesizing the mature power generation index insurance in foreign countries, this paper collects 57 distributed PV projects and takes the GHI data of distributed PV projects in Shaoxing City, Zhejiang Province, as a representative, obtains the GHI data from NASA, and explores the process and significance of constructing the power generation index insurance model based on ARIMA model by using the method of machine science.

1. Introduction

The significance of this study is mainly reflected in the following four aspects:

1) Improving the pricing accuracy of PV index insurance: accurate premium pricing can better reflect the risks and potential losses of PV systems and provide a reasonable level of premium, thus improving the fairness and sustainability of the insurance contract.

2) Improving the investment decision of PV systems: when considering the construction and operation of PV systems, investors need to comprehensively assess the potential risk and return. By building an index insurance with ARIMA model based on the collected GHI data, the transparency of the insurance contract is enhanced, and investors can better understand the risk characteristics of PV systems and consider the insurance coverage factors in their investment decisions, which will help to improve the risk awareness and decision-making effectiveness of investors.

3) Promoting the development and innovation of the PV insurance industry: However, due to the special characteristics of PV systems and the complexity of risks, the current premium pricing methodology has certain limitations. The results of this study can provide new pricing ideas and methods for the PV insurance industry and promote the innovation of insurance companies in product design and risk management. Provide scientific basis and risk management tools: There are certain uncertainties and risks in the investment and operation of PV systems, this study provides investors and insurance companies with scientific basis and decision-making support through the establishment of prediction models and risk assessment methods, which can help to formulate reasonable risk

management strategies and ensure the sustainable development and investment returns of PV systems.

In summary, the significance of this study is to improve the pricing accuracy of PV insurance, improve investment decisions, promote the development and innovation of the PV insurance industry, provide investors and insurance companies of PV systems with scientific basis and risk management tools, and, through these efforts, further promote the application and promotion of renewable energy sources and facilitate the realization of China's dual-carbon strategy.

In the theoretical research part, firstly, based on the research background and research significance, the necessity of the article's research is pointed out; secondly, the existing literature is sorted out, and the literature research is carried out on the basis of fully reading the relevant literature. In the ARIMA model, its content modeling steps are described, and then the four research directions of ARIMA are summarized. In distributed photovoltaic system, its feature model is described, and then its technology update, policy orientation, development status, and development prospect are summarized. In terms of index insurance, it summarizes the principles, origins, and application areas of index insurance, as well as the literature review of index insurance practice, and challenges faced [1].

In terms of empirical research, this paper firstly designs three models on the basis of theoretical research: based on the obtained GHI data, ADF test and LB test are firstly carried out in constructing the ARIMA model to test the stationarity and white noise. Then, based on the historical data of the project, the model of compensation amount and insurance premium rate was built and designed through the distribution model, and the expression of insurance premium rate was explained theoretically.

2. The fundamental of arima model

ARIMA model (Autoregressive Integrated Moving Average Model), was proposed by Box and Jenkins in the early 1970s, which is a famous time series forecasting method. ARIMA(p,d,q) is the differential autoregressive moving average model [2]. ARIMA(p,d,q) is an autoregressive moving average model; AR is autoregressive, p is autoregressive term; MA is moving average, q is the number of moving average terms, and d is the number of difference terms made when the time series is stationary. The so-called ARIMA model is a model that converts a non-stationary time series into a stationary time series and then regresses the dependent variable only on its lagged value and the present and lagged values of the random error term.

Distributed photovoltaic refers to the installation of photovoltaic power generation systems in various buildings, facilities or on the ground in the vicinity of users, and the operation mode is based on self-consumption, surplus power on the Internet, and power generation equipment for balanced regulation in the distribution system, and this kind of power generation facility not only meets the local demand for electricity, but also provides a certain degree of power supply to the main grid. Compared with the traditional centralized PV power generation system, distributed PV focuses more on installing the PV power generation system near the load, reducing transmission losses and grid pressure, and improving power utilization efficiency [3]. A PV system usually consists of PV modules, an inverter, a battery storage system and a grid connection. It can be installed in different places such as rooftops, walls, parking lots, agricultural fields, industrial areas, etc., to utilize the available space and resources for power generation. On this basis, distributed PV systems can exchange power with the grid in both directions, inputting excess power into the grid, while at the same time obtaining power from the grid when needed. Based on its flexibility, the distributed PV system can be installed on the roofs and walls of buildings and other locations, as well as on the ground in open spaces and farmlands. Its power generation capacity is relatively small, usually between tens of kilowatts and several megawatts. The object of electricity consumption is mainly to provide power to local buildings, facilities or areas to meet local power demand. On this basis, a distributed PV system can perform a two-way power exchange with the grid, injecting excess power into the grid while obtaining power from the grid. Generally speaking, distributed PV is a power generation method that distributes PV power generation systems in various locations to meet local power demand. It is characterized by flexibility, scalability and environmental friendliness, and is one of the important means to promote the utilization of renewable energy and reduce carbon emissions.

From the current literature, there are more research results on distributed photovoltaic, mostly combined with the historical background and development status of distributed photovoltaic in China, and analyzed from the aspects of policy orientation, distributed photovoltaic technology updating, and distributed photovoltaic development prospects. Firstly, large-scale grid integration of distributed PV is a necessary road for the development of distributed PV, and blockchain technology is an important means to quantify distributed PV power generation in the future, obtain real-time data through data terminals, screen port data, and control the whole situation [4]. Secondly, the national policy orientation is to vigorously promote the construction of distributed PV facilities, in distributed PV industry in all aspects, such as financial subsidies, plant construction, investigation and compensation of major safety facilities, etc. to give some policy support. Thirdly, under power quality and grid constraints, the literature raises the issue of optimal planning of distributed PV power generation and proposes corresponding solutions [5].Finally, most of the literature mentions several problems in the distributed PV industry: Distributed PV power generation has a number of relevant problems in its implementation process problems, firstly, distributed PV feed-in and grid scheduling problems: Distributed PV power access to the grid may lead to grid instability, and grid scheduling and operation problems need to be solved [6]. Secondly, technical and performance problems: Distributed PV power generation systems need to consider the technical issues such as the performance of the PV modules, the stability of the inverters, and the efficiency of the battery energy storage system [7]. Third, policy and regulation issues: Distributed PV power generation needs to comply with relevant policies and regulations, including feed-in policy, subsidy policy, and tariff policy [8]. Finally, social acceptance and environmental impact issues: Distributed PV power generation may have an impact on local communities and the environment, and social acceptance and environmental protection issues need to be considered [9-10].

3. Simulation Analysis

3.1 The establishment of data computation

Index insurance is an insurance product in which the premium and the amount of insurance are calculated in relation to the rise or fall of an index. Typically, this index can be a stock market index, commodity price index or other economic index. The insurance company will determine the change in premium and amount of insurance based on the movement of the index. If the index performs well, the premium may go up; conversely, if the index performs poorly, the premium may go down. This mechanism allows insurers to price more accurately and also provides a risk management tool for policyholders. As a form of insurance based on a specific index, it is simpler, more flexible and more responsive to specific areas of risk than traditional forms of insurance. It can provide more flexible insurance coverage that can be adjusted to market conditions. It can also provide an investment opportunity for policyholders, as they can participate in the ups and downs of an index by purchasing index insurance. Over the past few decades, index insurance has been widely used in areas such as agriculture, tourism and energy.

Data Source: National Aeronautics and Space Administration (hereinafter referred to as:NASA) (https://power.larc.nasa.gov/) in the NASA released GHI meteorological data and parameters are based on Goddard global modeling and assimilation (GMAOs) office, by the instrument team (FP - IT) reference for modern research and application of retrospective analysis, Assimilation model products and GMAO forward processing of near real-time products. The data spans a period from 1981 to several months in real time. The solar data parameters are based on satellite observations and inversion to surface solar insolation based on the Surface Radiation Budget (SRB) and NASA's CERES Fast Long and Short Wave Radiation Project (FLASHFlux). Model 1, 2, and 3 are analyzed based on GHI data of 104MW rooftop sub-photovoltaic projects in Shaoxing, Zhejiang. (E 120.49476 N 30.08189) Data collection process: First, distributed photovoltaic power generation projects that have been under construction or built are retrieved according to the North Star solar photovoltaic network, and then the corresponding longitude and latitude 9 coordinates are searched according to the project address. Then the latitude and longitude coordinates are used to read the API interface using python from the NASA PV database, and the GHI satellite data of the corresponding location is exported for analysis.

For seasonal ARIMA model, first of all, white noise test should be carried out to determine whether the data is pure random data. Therefore, the Ljung-Box test is applied to test the hypothesis:

Null hypothesis (H0): the values of the M-order delayed sequence are independent of each other, and the sequence is independent and equally distributed white noise.

Alternative hypothesis (H1): the values of the M-order delayed sequence are correlated, and the sequence is not independent and equally distributed white noise.

Using stats models. Stats. LB inspection diagnostic module, get the above calculation results, found that the final P values are less than 0.01 inspection results refused to false, the alternative hypothesis, sequence under the confidence level of 99% belong to the white noise (independent identically distributed.

First of all, the data of Zhejiang Province in the past 39 years are displayed by using time series graphs, which can directly and preliminarily judge the seasonality of the current data in the figure 1.

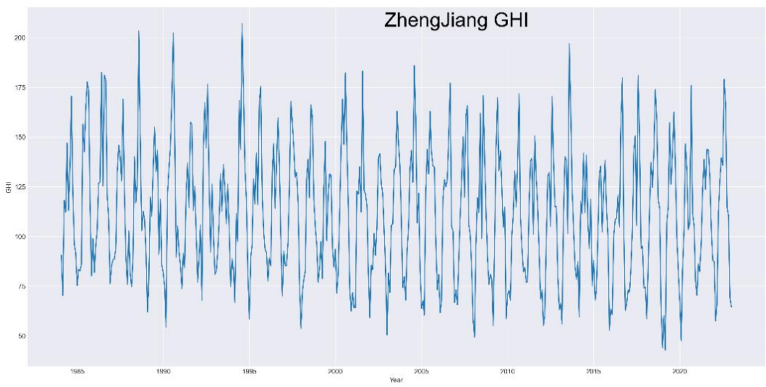

Figure 1: Time series plot

To ensure accuracy, unit root tests will be performed using ADF tests. Also used stats models. Tsa. Stattools module, ADF test, finally get the following results.

Table 1: Parameter Values

Parameter	Value
Test Statistic	-4.24800
p-value	5.45892e-4
Lags Used	11
Number of Observations Used	456
Critical Value1%	-3.44477

In the above table 1, the P-value level corresponding to the T-test value is 5.45892×10−4, which is far less than 1%, so it also passes the ADF stationarity test and is a stationary series.

For ARIMA (p, d, q), (p, d, q, S) parameters, we set S = 12 and then use stats models. Tsa. Statespace. Sarimax module for grid search of reference parameters, and parameters required for the constructed model of the initial value is set to AIC is minimal. Taking the parameters obtained from the grid as reference, and comprehensively considering indexes such as MAPE, coefficient significance of parametric equation, normality test of residual, etc., the optimal ARIAM fitting parameter was finally determined as (1,0,1), and (2,0,1,12)AIC value was 4012.236.

The fitting effect of the model is as shown in table 2.

Table 2: Results of fitting parameters

	Coef	Std Err	Z
ar.L1	0.9901	0.016	63.552
ma.L1	-0.9701	0.024	-39.599
ar.S.L12	0.9996	0.000	2611.568
ma.S.L12	-1.0235	0.029	-34.700
ma.S.L24	0.0842	0.003	24.075
sigma2	232.8496	13.943	16.701

We will fit the ARIMA model with 468 months from '84 to' 22, select the last 60 months of the sample in the model to show, and make predictions for the last 12 months. Figure 2 is the ARIMA's forecast for the next five years.

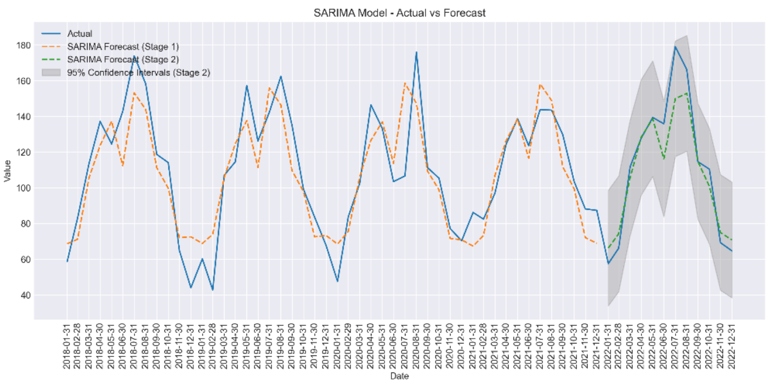

Figure 2: ARIMA's projection for the next five years

4. Conclusions

Under the call of the national dual-carbon strategy, distributed photovoltaic has become an important development direction for energy development with its unique model and energy structure, while the distributed photovoltaic industry has a unique risk structure, which started late in China, and lacks appropriate risk measurement and prediction models.

In this paper, we measure and estimate the risk of distributed PV in the field of solar radiation, which is the basis of solar power generation, because insufficient solar radiation can seriously affect the level of power generation. This index-based insurance design manages the impact of lack of solar radiation on energy production. It is based on solar radiation to determine index triggers and payments. It also helps to speed up claims processing and avoids adverse selection and moral hazard debates (since neither the insurer nor the insured can influence the index).

Solar energy resources depend on the geographic location of solar radiation. The energy assessment in this study comes from satellite estimation of surface data because satellites can provide spatial historical time series and continuous solar radiation values, which can well compensate for the difficulties in insurance product design caused by insufficient data samples due to the late start of distributed PV in China. Meanwhile, index insurance for power generation base stations is mainly measured through satellite data. Combined with ground-based solar radiation measurement further improves the accuracy of product prediction, and the methodology can also be well balanced for insurance companies to balance product approval in terms of cost.

As the index can better quantify the risk in this area, it provides investors with an investment measure that can, to a certain extent, increase the confidence of investors, lenders and insurers. With this data, forecasts of solar resources and energy production can be used more accurately for financial analysis, and index insurance can further link the underlying risks. At the same time, as an insurance product, it can better endorse insurance for generating units, stabilize enterprise cash flow, and promote enterprises to obtain a lower financing threshold; for insurance companies, distributed photovoltaic insurance is almost a late-starting emerging market, and in this promising field, a suitable insurance product can make insurance companies more competitive in the market and gain more revenue.

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