Scholar Publishing Group
Academic Journal of Energy
https://doi.org/10.38007/RE.2022.030403
ISSN 2790-2714 Vol. 3, Issue 4: 23-32

Spatial Distribution of Solar Energy (SE) and Comprehensive Potential Evaluation of Regional Development and Utilization Based on Deep Learning

Tao Li*, Shili Liu, Fan Yang, Yue Tang and Jianqing Li

Economic and Technological Research Institute of State Grid Anhui Electric Power Co., Ltd, Hefei 230031, China

**corresponding author*

Keywords: Deep Learning, Solar Energy, Spatial Distribution, Potential Evaluation

Abstract: Energy is the fundamental driving force for social development and the material basis. In the social process from ancient times to the present, energy has always been closely related to it and is inseparable from time to time. With the continuous improvement of the level of human civilization, the role of energy has become more and more prominent, the scope of its influence has become wider and wider, and its role has become more and more important. The main purpose of this paper is to evaluate the spatial distribution of SE and the comprehensive potential of SE development and utilization based on deep learning algorithms. In order to more accurately and quantitatively describe the correlation between each parameter and photovoltaic power, this paper selects the Pearson correlation coefficient for quantitative analysis. Experimental research shows that irradiance and photovoltaic power have the greatest correlation, followed by temperature and wind speed. Through analysis, parameters such as irradiance, temperature, wind speed, wind direction and humidity can be selected for photovoltaic power prediction research.

1. Introduction

Energy supports social development and is the material guarantee for social and economic development. The distribution of energy also presents different characteristics due to the differences in the geographical environment of each region. With the depletion of conventional energy, the large-scale development and utilization of renewable energy is an inevitable trend. As an important renewable resource, SE will inevitably be developed and utilized on a large scale in the future social development. It has become a major energy policy in my country. Therefore, it is of great significance to understand the spatial distribution characteristics of SE resources in my country, analyze its changing trends, reasons for changes, and grasp the characteristics of the resources themselves, for my country to make more rational use of SE, adapt measures to local conditions, improve the utilization efficiency of SE, and save energy and reduce emissions [1- 2].

In a related study, Sahin et al. provide an updated review of various recent studies illustrating the use of nanofluids in different types of solar collectors to enhance their performance [3]. Furthermore, given the general challenges of using nanofluids in solar systems, some suggestions are made for future research directions. Proper dispersion of nanoparticles has been seen to be a key issue for adequate SE absorption. Nirmal et al. proposed a grid-connected SE conversion system (SECS) [4] based on a binary hybrid multilevel inverter (BHMLI) controlled by a damped second-order generalized integral (DSOGI). The BHMLI architects have a cascaded half-bridge array that modifies the DC link of the H-bridge of the voltage source inverter and produces an approximate reference waveform. It reduces the dV/dt of the H-bridge switch and improves the output waveform quality. DSOGI control suppresses ringing and overshoot, and provides longer low-power switching service life under transient conditions.

This paper firstly introduces the attributes of SE resources, mentions the construction principle of the potential evaluation index system, and defines the potential of SE utilization; analyzes various comprehensive factors that affect the development potential of SE in the region, and briefly describes the relationship between each comprehensive factor and development potential. The development potential under each comprehensive factor is also shown, which provides the necessary foundation for constructing the development potential index system.

2. Design Research

2.1. Properties of SE Resources

As a new type of energy, compared with other energy sources, SE has its own attributes and advantages [5-6].

(1) Huge supply. With the increasing depletion of conventional energy sources, it is imperative to seek new energy sources, and SE resources are an alternative energy source for future social development. Although the sun itself undergoes a chemical reaction of fusing oxygen into helium, consuming its own energy, this reaction can last for billions or even tens of billions of years. Compared with the history of the earth itself, which is about 4.5 billion years old, This time limit can be regarded as infinite for human beings.

(2) The generality of the distribution. Where there is sunlight, there are SE resources. Although the difference in climate, degree, altitude, etc. has caused the uneven distribution of solar radiation, compared with other energy sources, it is widely distributed and can be used locally to a certain extent. Its wide distribution also provides a good way of energy utilization for countries and regions lacking conventional energy [7-8].

(3) The use of environmental protection. Environmental degradation and carbon emissions have become global issues, and the future development of society will pay more attention to efficient and clean energy use. As green energy, it also does not generate CO2, which causes climate warming, which is the characteristic required for human ideal energy.

(4) Economic feasibility. On the one hand, receiving and utilizing SE resources does not need to pay any "tax" and can be used anywhere. On the other hand, in terms of heat utilization, it has a strong competitive advantage.

In addition, the advantage of SE lies in its safety in the process of utilization, no noise, easy acceptance by users, short construction period, short energy consumption time, no need for transportation, high flexibility, etc. [9-10].

2.2. Construction Principles of Potential Evaluation Index System

The available space for urban SE is closely related to the legal provisions issued by relevant departments, the normative standards formulated, the relevant planning theories, the experience of developing SE cities in various regions, and the profound connotations represented by various influencing factors. The target layer of the system has profound connotations. The evaluation process involves multi-disciplinary research fields such as urban and rural planning, landscape architecture, new energy development and smart grids. It is necessary to scientifically evaluate the available space for SE by combining different research methods. In the process of selecting and constructing the evaluation index system, it is necessary to select the evaluation indicators suitable for the urban environment and spatial form according to the connotation of the target layer, taking into account the urban humanistic characteristics. The following three principles need to be followed to guide the construction of the evaluation index system [11-12].

(1) Systematic and comprehensive principles

The evaluation index must be able to reflect the typical characteristics of the urban SE available space, taking into account the SE resource conditions and the measurement of the urban built environment to avoid errors. In the urban environment, the most significant feature is the interaction between urban space and SE usable space, reflecting the combination of urban planning and solar urban planning. Urban SE usable space evaluation is an intervention process for urban planning and urban design from the perspective of new energy. The evaluation process is regarded as a system, and the evaluation index system is systematic and comprehensive. The evaluation indicators can neither overlap nor omit, and can reflect the regional division and time series evolution of the urban SE usable space. Only starting from a single disciplinary perspective is likely to lead to a single development model of SE available space, and it is impossible to reflect the integrity of planning from different perspectives. Therefore, the selection of evaluation indicators should be comprehensively analyzed from a multidisciplinary perspective, striving to be systematic and comprehensive in the evaluation results, and insist on building a space for SE utilization with practicality and development space [13-14].

(2) The principle of hierarchy and independence

It is necessary to ensure the independence of each evaluation index and the hierarchy of the evaluation index system. According to the overall research objectives, at the same time, ensure that the evaluation indicators are independent of each other, each indicator has a unique connotation and interpretation method, and the relationship between the indicators is clear and clear. The indicators at the same level are juxtaposed with each other to avoid overlapping. This principle is a strong support for scientific judgment of evaluation results and achievement of research objectives.

(3) Principles of feasibility and operability

"Selecting the evaluation index - constructing the evaluation index system - completing the evaluation of the urban SE available space" is the technical route to guide the practice, and the selection of the evaluation index should consider the feasibility and operability. The principle of feasibility mainly means that the data of the evaluation indicators are feasible for analysis, which can reflect the constraints of the construction of urban SE usable space, and it is of practical significance to maintain the evaluation results. The principle of operability is to ensure that the data materials involved in the evaluation indicators are easily available, the data sources are reliable, and the data processing is accurate. Qualitative and quantitative indicators may coexist in the evaluation index system. Generally speaking, quantitative indicators are the main ones, and indicators that cannot be quantified can be converted into qualitative indicators for description. The data sources of the evaluation indicators should be consistent with the acquisition channels as much as possible, and necessary corrections and improvements can be made to the missing data to ensure the accuracy and credibility of the evaluation results of the visualized urban SE available space [15-16].

2.3. Definition of SE Utilization Potential

In the current study, the SE potential is divided into three levels: solar physical potential, solar geographic potential, and solar technical potential [17-18]. These three levels of solar potential represent SE from natural resources to energy that can be utilized. , showing a progressive relationship:

(1) The physical potential of SE is the total amount of radiant energy reaching the ground by solar radiation, which is mainly affected by radiation intensity and meteorological conditions;

(2) The geographical potential of SE is the total amount of solar radiation that can be received by the roof of the building, which is mainly affected by the available area of the roof and the surrounding shading;

(3) The potential of SE utilization, the use of solar panels or collectors to convert solar radiation into electrical energy or thermal energy, is mainly affected by the type and performance of the equipment and the area covered by the installation.

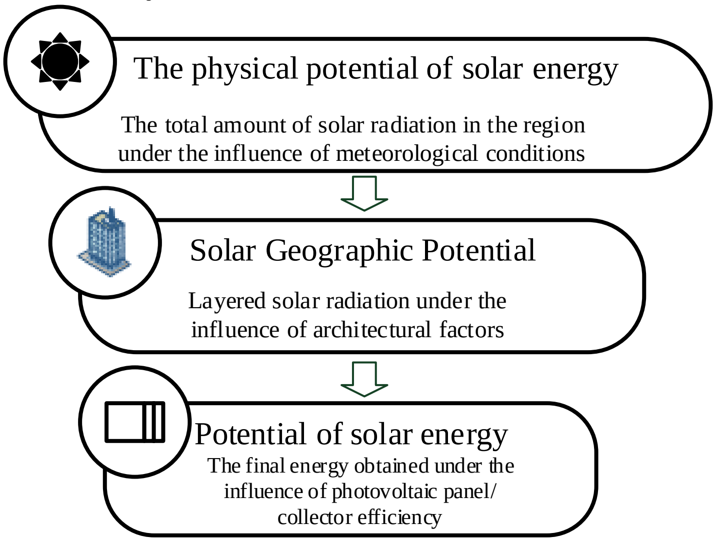

Figure 1. Solar potential grading

2.4. Algorithm Research

(1) Potential score

In this paper, the calculation method of the potential score of SE resources is adopted, and the quantitative factors are added up after assigning them in a hierarchical manner.

The calculation formula is:

$$P_{Total} = \frac{1}{n}\sum_{i=1}^{n} p_i \tag{1}$$

Among them, Pi is the graded value of each quantization factor; n is the number of quantization factors; PTotal represents the total score of resource development potential.

After the total score is obtained, in order to highlight the obvious rich areas and poor areas, the spatial distribution of the potential of my country's SE resources is divided into extremely high-quality resources, high-quality areas, good areas, general areas, poor areas and poor areas.

(2) Correlation analysis of various factors

In order to more accurately and quantitatively describe the correlation between each parameter and photovoltaic power, the Pearson correlation coefficient was selected for quantitative analysis. The formula for calculating the Pearson correlation coefficient is shown in formula (2):

$$\rho(x,y)\frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{(\sum_{i=1}^{n}(x_i-\bar{x})^2\sum_{i=1}^{n}(y_i-\bar{y})^2)^{\frac{1}{2}}} \tag{2}$$

where $\bar{x}$ is the mean of x and $\bar{y}$ is the mean of y.

(3) k-means training algorithm

The process of dividing some collection of objects into a class of similar objects is called cluster analysis. The main purpose of clustering is to divide the sample into several disjoint "clusters". The k-means clustering algorithm can achieve better results on large-scale datasets. The k-means clustering algorithm classifies the data into k classes, each with a class center μk. The Euclidean metric is chosen as the criteria for similarity and distance, and the sum of squares of the distances between points in each class and the center of class μk is calculated to minimize the sum of squares within each class. The objective function of the k-means algorithm is written as:

$$V=\sum_{j=1}^{k}\sum_{i=1}^{\omega_j}\left\|x_i^{(j)}-\mu_k\right\|^2 \tag{3}$$

The performance of the k-means clustering algorithm is affected by many factors, mainly in two parts: the number of clusters k and the initial mean vector. The choice of the initial mean vector is related to the efficiency of the algorithm. There are many ways to initialize the mean vector. The k-means algorithm requires that the user must provide the number of k in advance, and the value of the standard function varies with cluster k. The choice of the k value determines whether the classification is reasonable. Usually the k value is customized by humans, and it is necessary to continuously adjust the k value to achieve the optimal value. Although this is effective, it is inefficient.

(4) Elbow method:

The elbow method mainly relies on the sum of squares of errors (SSE) to determine the k value, and the formula is:

$$SSE=\sum_{j=1}^{k}\sum_{p\in c_i}\left|p-m_i\right|^2 \tag{4}$$

where ci is the ith cluster and p is the sample point. mi is the centroid (sample mean). SSE is the clustering error of all samples, which represents the quality of the clustering effect.

When k increases, the samples will be divided more and more finely, then the aggregation degree of the samples in each class will become higher and higher, and the corresponding SSE value will become smaller and smaller.

3. Experimental Study

3.1. Types of My Country's SE Industry

(1) Solar thermal utilization industry

The heat utilization industry is currently mainly used in eight fields in my country, namely:

Industrial development of solar low-temperature hot water integration technology aiming at high efficiency, all-weather safety, and intelligent control.

Application of split pressurized solar water heating system. Taking the production of solar enamel water tanks as an example, there are many enterprises with large-scale production capacity in my country.

Efficient development of flat-panel solar collectors. In the new situation, the innovation of flat-panel solar collector technology has greatly improved its output and performance. In 2018, my country's flat-panel solar water heaters accounted for about 10,000 of all water heaters in that year.

Promotion of solar heating and air conditioning technology. At present, my country has successfully operated several sets of solar air conditioning systems, with more than ten sets of different power systems, and solar heating projects have been carried out in many cities and villages.

The solar medium and high temperature collector industry continues to grow. Linuoguang Group, Hebei Light Source, Huangming Group and many other companies are conducting R&D and production.

The popularity of active and passive solar houses and solar cookers.

Application of solar thermal utilization in industry and agriculture. So far, significant breakthroughs have been made in the construction of crop drying projects, seawater desalination projects, industrial hot water projects and intelligent greenhouses, and related industries and enterprises are also improving day by day. In the process of application, the environmental benefits are also very obvious.

Development of heat collection and storage for thermal power generation. The establishment and operational use of solar thermal power plants are the main hallmarks of this field.

(2) Photovoltaic industry

The solar photovoltaic industry chain is mainly composed of the following links, as shown in the following figure:

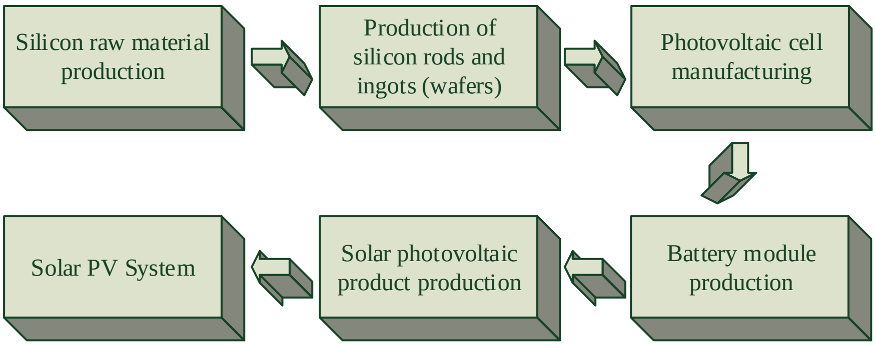

Figure 2. Schematic diagram of the structure of the photovoltaic industry chain

3.2. The Main Factors Affecting the Development and Utilization of SE Resources

For a long time, the geographical area of human production activities is not completely dominated by subjective factors, but is restricted by various factors, such as land, raw materials, labor force, capital, and technological level. The same is true for the utilization of SE resources by human beings. The factors affecting the utilization of SE resources are not completely consistent with the different ways of using them. Generally, there are mainly the conditions of SE resources, land conditions, consumption level, policy guarantee, technical level, technology cost etc. Since there is no obvious difference in the technical level and technical cost of SE development and utilization at the national level, the development potential of SE resources in various regions in my country can be compared without considering these two factors. Starting from the objective of evaluating the potential of SE development and utilization in various regions, referring to Wang Jian et al.'s research on the optimal development of wind energy resources in my country, four comprehensive factors are used to illustrate the development potential of SE resources in various regions of my country.

(1) Conditions of SE resources themselves

The SE resource itself is affected by factors such as climate, altitude, temperature, sand and dust, but the comprehensive impact results are reflected in three aspects of the SE resource itself: annual radiation, sunshine hours and effective sunshine days.

(2) Land

Since the utilization of SE resources requires land as its carrier in geographical space, and the power density of SE in my country is low, factors such as land type, terrain and land area affect the utilization of SE resources. Especially in terms of large-scale utilization, it is obvious that land types such as Gobi and desert are more suitable than other types of large utilization value such as grassland and cultivated land, and flat terrain and wide area are more conducive to the development and utilization of SE.

(3) Consumption level

The influence of consumption level on the development of SE resources in various regions can be reflected by regional power consumption, net power input, and regional economic development level. The regional power net input reflects the degree of power shortage in each region. The larger the regional power input, the stronger the internal motivation of the region to develop SE resources. The higher the living standard of people, the higher the energy consumption, and the more necessary to develop and utilize SE in the area or surrounding area.

(4) Policy guarantee

The development and utilization of SE is inseparable from the support of national and regional policies, especially in the aspect of large-scale development and utilization. It can be reflected in three aspects: first, the incentive policy for the large-scale development of SE; second, the financial support; third, the government's attention. All in all, the higher the regional policy guarantee, the greater the regional development potential.

4. Experiment Analysis

4.1. Classification of Solar Resource Potential

The spatial distribution of each characteristic quantification factor of the SE resource itself is analyzed separately. To develop and utilize SE on a large scale, the comprehensive potential of the resource itself needs to be considered. For the analysis of the potential of the SE resource itself, this paper starts from the perspective of spatial superposition of the spatial distribution of the three characteristic quantification factors of the SE resource itself, adopts the factor classification comprehensive evaluation method, and divides each factor into five levels, with the highest quantification factor. The number is used as a threshold, and a graded assignment is given. In order to highlight the rich range of resources, the interval range of each quantification factor is divided as follows. as shown in the table below.

Table 1. Grading of the development potential of SE resources itself

Comprehensive grade	Grading value	Annual radiation dose (MJ/m2)	Annual sunshine hours (h/a)	Annual effective sunshine days (d/a)
1	100	>6800	>3100	>340
2	80	6200~6800	2700~3100	310~340
3	60	5400~6200	2300~2700	250~310
4	40	4300~5400	1900~2300	210~250
5	20	<4300	<1900	<210

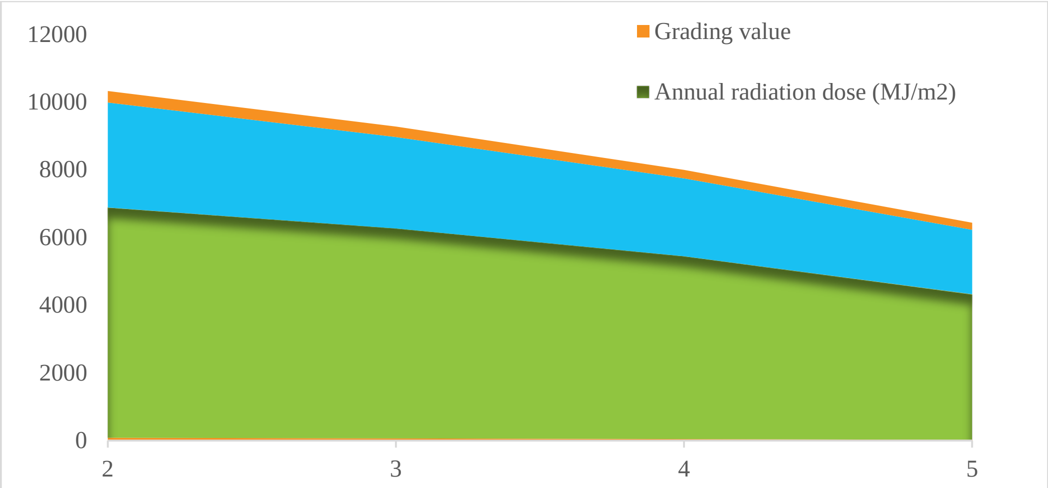

Figure 3. Grading diagram of the development potential of SE resources itself

4.2. Correlation Coefficient

Table 2 shows the correlation coefficient values between the parameters obtained by using the Pearson correlation coefficient.

Table 2. Correlation coefficients between parameters and photovoltaic power

	Pearson correlation coefficient					
different parameters	Photovoltaic power	radioactivity	temperature	wind speed	wind direction	humidity
radioactivity	0.9536	1.0000	0.5083	0.5803	-0.1883	-0.4721
temperature	0.8452	0.5083	1.0000	0.5240	-0.2422	-0.6527
wind speed	0.5908	0.5803	0.5240	1.0000	-0.2583	-0.4055
wind direction	-0.4421	-0.1883	-0.2422	-0.2583	1.0000	0.2184
humidity	-0.4662	-0.4721	-0.6527	-0.4055	0.2184	1.0000
Photovoltaic power	1.0000	0.9536	0.8452	0.5908	-0.4421	-0.4662

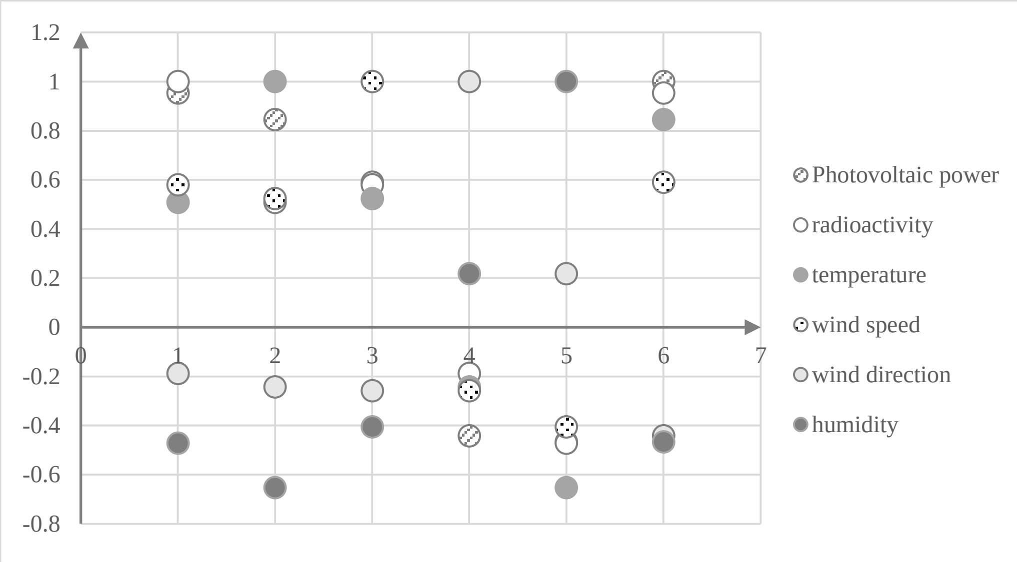

Figure 4. Analysis of the correlation coefficient between each parameter and photovoltaic power

It can be seen from the figure that the correlation between irradiance and photovoltaic power is the largest, followed by temperature and wind speed. Through the above analysis, parameters of irradiance, temperature, wind speed, wind direction and humidity are selected for photovoltaic power prediction research.

5. Conclusion

Stable energy supply is the premise and guarantee for sustainable social production and economic growth, and people's highly standardized and diversified lifestyles also require more and more energy supply. The deep learning method can build an end-to-end learning model, so the prediction of photovoltaic power generation can learn the multi-dimensional information in the meteorological data, and its powerful data processing capability. The utilization of SE resources in my country has great potential, and the photovoltaic power generation industry, especially the promotion of distributed photovoltaic power generation, is still in the stage of rapid development. Therefore, accurate photovoltaic power generation forecasting technology can meet the needs of the region for the regulation of SE resource utilization, and can also be used for the follow-up. The widespread application of distributed photovoltaic power generation provides support.

References

[1] Bhimala K R , Gouda K C , Himesh S . Evaluating the Spatial Distribution of WRF-Simulated Rainfall, 2-m Air Temperature, and 2-m Relative Humidity over the Urban Region of Bangalore, India. Pure and Applied Geophysics, 2021, 178(1):1-16. https://doi.org/10.1007/s00024-021-02676-4

[2] Yasser, Morera-Gómez, Carlos, et al. Levels, spatial distribution, risk assessment, and sources of environmental contamination vectored by road dust in Cienfuegos (Cuba) revealed by chemical and C and N stable isotope compositions. Environmental Science and Pollution Research, 2020, 27(2):2184-2196. https://doi.org/10.1007/s11356-019-06783-7

[3] Sahin A Z , Uddin M A , Yilbas B S , et al. Performance enhancement of solar energy systems using nanofluids: An updated review. Renewable energy, 2020, 145(Jan.):1126-1148.
[4] Nirmal M , Jayaprakash P , Subramaniam U , et al. Binary Hybrid Multilevel Inverter-Based Grid Integrated Solar Energy Conversion System With Damped SOGI Control. IEEE Access, 2020, PP(99):1-1.
[5] Zeman M . Developing the future electricity grid. Europhysics News, 2021, 52(5):32-35. https://doi.org/10.1051/epn/2021505
[6] Lima M , Carvalho P , LM Fernández-Ramírez, et al. Improving solar forecasting using Deep Learning and Portfolio Theory integration. Energy, 2020, 195(Mar.15):117016.1-117016.14. https://doi.org/10.1016/j.energy.2020.117016
[7] Falahudin D , Cordova M R , Sun X , et al. The first occurrence, spatial distribution and characteristics of microplastic particles in sediments from Banten Bay, Indonesia. The Science of the Total Environment, 2020, 705(Feb.25):135304.1-135304.10.
[8] Ghatak S R , Sannigrahi S , Acharjee P . Multi-objective Framework for Optimal Integration of Solar Energy Source in Three-Phase Unbalanced Distribution Network. IEEE Transactions on Industry Applications, 2020, PP(99):1-1.
[9] Andres-Manas J A , Roca L , Ruiz-Aguirre A , et al. Application of solar energy to seawater desalination in a pilot system based on vacuum multi-effect membrane distillation. Applied Energy, 2020, 258(Jan.15):114068.1-114068.13. https://doi.org/10.1016/j.apenergy.2019.114068
[10] Liu Z , Mohammadzadeh A , Turabieh H , et al. A New Online Learned Interval Type-3 Fuzzy Control System for Solar Energy Management Systems. IEEE Access, 2021, PP(99):1-1.
[11] Boretti A . Production of hydrogen for export from wind and solar energy, natural gas, and coal in Australia. International Journal of Hydrogen Energy, 2020, 45(7):3899-3904.
[12] Sahu A , Garg A , Dixit A . A review on quantum dot sensitized solar cells: Past, present and future towards carrier multiplication with a possibility for higher efficiency. Solar Energy, 2020, 203(16):210-239. https://doi.org/10.1016/j.solener.2020.04.044
[13] Karatu A , Durmusoglu Y . Design of a solar photovoltaic system for a Ro-Ro ship and estimation of performance analysis: A case study. Solar Energy, 2020, 207(C):1259-1268.
[14] Rathore S , Park J H . A Blockchain-based Deep Learning Approach for Cyber Security in Next Generation Industrial Cyber-Physical Systems. IEEE Transactions on Industrial Informatics, 2021, 17(8):5522-5532. https://doi.org/10.1109/TII.2020.3040968
[15] Benning M , Celledoni E , Ehrhardt M J , et al. Deep learning as optimal control problems. IFAC-PapersOnLine, 2021, 54(9):620-623. https://doi.org/10.1016/j.ifacol.2021.06.124
[16] Pollok S , Bjrk R . Deep learning for magnetism. Europhysics News, 2022, 53(2):18-21. https://doi.org/10.1051/epn/2022204
[17] Adler A , Araya-Polo M , Poggio T . Deep Learning for Seismic Inverse Problems: Toward the Acceleration of Geophysical Analysis Workflows. IEEE Signal Processing Magazine, 2021, 38(2):89-119. https://doi.org/10.1109/MSP.2020.3037429
[18] Qamhan M A , Alotaibi Y A , Seddiq Y M , et al. Sequence-to-Sequence Acoustic-to-Phonetic Conversion Using Spectrograms and Deep Learning. IEEE Access, 2021, PP(99):1-1.