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Multi-Combination Method for Intelligent Remote Sensing of Solar Energy Resources in Different Regions

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Abstract. Solar energy is the main means of new energy development, which has the characteristics of a clean, safe and wide range of resources, but there are problems of large differences in radiation and heat in the process of solar energy collection, and how to effectively utilize solar energy resources is the focus of current research In order to improve the utilization effect of solar energy resources, this paper proposes a multi-component remote sensing analysis method based on remote sensing. Firstly, the solar energy resources were quantitatively analyzed to construct the solar energy resource utilization set. Then, with the help of multiple combination indicators such as solar trajectory, direct inclination, and light intensity, intelligent remote sensing judgment was carried out on solar energy resources. Finally, compared with a single measurement method, the utilization accuracy, utilization amount and utilization cost of solar energy resources are verified. The results show that the multivariate combination method can remotely sense solar energy resources in different regions and times, with a control rate of 56%, and a solar energy utilization set with an increase rate of 20%. Moreover, the multi-combination method can expand the control area of solar energy resources, and the expansion rate can be increased by 10%. Therefore, the multi-combination method can improve the utilization rate of solar energy resources, reduce labor costs and management costs, and increase power generation, which is better than a single measurement method.

Key words. Multi-combination Approach, Different Regions, Solar Energy Resources, Intelligent Remote Sensing.

1. Introduction

Alas, climate change is one of the most serious ecological security problems facing the world today, threatening the survival and sustainable development of human society. In order to cope with climate change and implement a carbon neutrality strategy [1], the development of new energy technologies will become the best solution to solve the current problems. Nowadays, there are many types of new energy sources, and solar energy also has a comparative advantage over wind, hydro, nuclear [2], etc. The Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission (NDRC) issued the Implementation Plan for Carbon Peaking in the Field of Urban-Rural Construction [3], proposing an energy development strategy to optimize the energy utilization structure of urban construction. Solar energy is often used to convert energy in a sunny environment, which is very sensitive, and at the same time [4], the installation of photovoltaic systems is also a clear benefit to make the most of idle resources. The National Energy Administration (NEA) issued the National Energy Comprehensive New Energy [2021] No. 84 Notice, announcing the pilot development of carrier distributed photovoltaics, high-resolution remote sensing data, and carrier photovoltaic potential assessment planning data, which will support the smooth development of energy-carrying photovoltaics across the country [5]. Solar PV projects have formed a certain scale, and while the production cost of solar PV panels has dropped significantly, the carbon neutrality and large-scale environmental economic benefits generated by carbon credits will be considerable [6]. At present, the research on intelligent remote sensing of solar energy resources mainly focuses on photovoltaics, and expounds the content of household rooftop photovoltaics and industrial photovoltaics, but lacks the intelligent detection of multiple combination methods, and ignores the more functional value of solar energy resources [7], [8]. In order to further improve the utilization rate of solar energy resources, this paper analyzes solar energy resources in different regions from the aspects of solar energy type, inclination angle and carrier. At the same time, the intelligent remote sensing system is used to monitor solar energy resources and improve the resource acquisition rate. Compared with a single measurement method, the effectiveness of the proposed method is verified, and the main research contents of this paper are as follows.

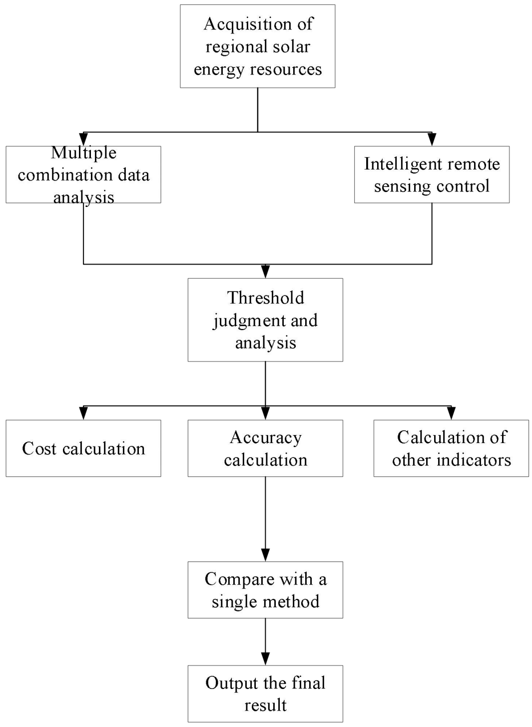


Figure 1. Steps of Intelligent Remote Sensing of Solar Resources

Firstly, solar energy resources in different regions were obtained and analyzed. Secondly, a variety of data combinations such as inclination angle and carrier were obtained, and the corresponding calculation model was constructed. At the same time, the remote sensing information of solar energy resources is calculated and compared with a single model. Finally, determine whether the calculation results meet the requirements, if they do not meet the actual requirements, perform iterative analysis, and repeat steps 1~3.

2. Mathematical Description of Solar Resource Development

A. Solar Remote Sensing in Different Regions

When using high-resolution remote sensing images to extract information, it is necessary to conduct an in-depth analysis of the original image data in order to more effectively identify the target of solar power generation. In this paper, considering the geometrical [7], [8], spectral and texture characteristics of the sample collection, the panchromatic image is fused with the multi-spectral data of R, G, and B bands to construct a solar panel power collection $p=\left(p_1,p_2,\cdots,p_n\right)$. Assuming that the area of sunlight is loc_i , the irradiation intensity is $f\left(p\right)$ assuming, and the illumination time is assumed T_i , the sunlight intensity in that area is shown in equation (1).

$$\hat{f}\left(p\right)=\frac{1}{n\cdot h}\sum_{i=1}^{n}K\cdot\left(\frac{p-p_i}{h}\right)\Big|T_i \tag{1}$$

where: n - the amount of sunlight intake; p_i - sunlight power, in which the $i\in\left[1,n\right];K\left(\cdot\right)$ angle of illumination, the shape of sunlight at any point is estimated; The uncertainty parameter is h , Control Lighting Point. For the illumination power, the probability intensity function is $f\left(p\right)$ [9], and the estimation calculation is shown in Eq. (2).

$$\hat{f}\left(p\right)=\frac{1}{n_i h}\bigotimes\sum_{i=1}^{n}\phi\left(\vec{p},p_i\right) \tag{2}$$

In the process of remote sensing, uncertainties such as received signals, weather, and equipment are affected, so Gaussian kernel estimation is required, as shown in Eq. (3):

$$\phi\left(p,p_i\right)=\frac{1}{\sqrt{\sin\theta}}\exp\left[n\cdot\left(\frac{p-p_i}{h}\right)^2\right] \tag{3}$$

B. Solar Energy Conversion and Storage

Therefore, solar energy conversion and storage is an important part of remote sensing control, and how to effectively analyze the scale of this problem, the conversion problem of a single solar panel [10] and the acquisition of corresponding data, and the coupling from the perspective of spectral and geometric features are the main aspects of solar energy conversion and storage [11],[12]. In addition, how to effectively use kilometer batteries for energy storage and highway discharge is also the focus of research, and the specific content is as follows. Hypothesis 2: The photon conversion rate is y_i the environment and te_i the angle of the photovoltaic panel J_i [13], and the solar energy conversion and storage are shown in Eq. (4).

$$y_i=\sum_{i=1}te_i\cdot J_i \tag{4}$$

At the same time, according to the peak rate estimation of the minimization principle, the angle of the solar panel is calculated, the light energy at any time is obtained by the cyclic progressive method X_i, and the variance is calculated to σ^2 make it conform to the normal distribution cluster, and the solar energy conversion and storage estimation is made, which is derived as shown in Eq. (5).

$$h_0 = \left(\frac{4}{3}\right)^{\frac{1}{5}} \hat{\sigma} n^{\left(-\frac{1}{5}\right)} \tag{5}$$

where: $\hat{\sigma} = \sqrt{\sum_{i=1}^{n} \frac{\left(X_i - \bar{X}\right)^2}{n-1}}$ belongs to the mean value of solar conversion.

C. Policy, Climate and Other Constraints

Climate and policy are the key parameters that interfere with the application of solar energy resources, and the power generation h_i [14], humidity s_i and sunshine time of solar photovoltaic panels T_i are closely related [15],[16]. In this study, the adjustment coefficient is increased according to the quarterly estimate to improve the accuracy of remote sensing control. The illuminance coefficient is the ratio of the number of sunshine days to the number of days in the quarter day, and the ratio of the number of sunshine days to the number of days in the four seasons $Aday$ [17], and D_s the calculation of the constraints is shown in Equation (6).

$$D_s = \frac{day}{Aday} \bullet \sum h_i \cdot s_i \cdot T_i \tag{6}$$

Comparing different sunny days, or abnormal weather at the high and low end of humidity, the relationship ϖ_i between sunshine time and constraints is shown in Equation 4 by using the weight coefficient intervention.

$$D_s = \varpi_i \bullet yday \tag{7}$$

where the sequence definition domain is $\varpi_i \in [0,1]$. At the same time, because the solar energy resources present a photovoltaic matrix arrangement, it is necessary to calculate the maximum amount of solar radiation that can be received by its intelligent inclination[18],[19]. Due to the continuous change of solar height, the optimal inclination angle of photovoltaic arrays will be different in different regions and different seasons, so to maintain the maximum irradiation, the optimal inclination σ calculation formula (8) is shown.

$$\sigma = k \bullet \sin\left[\frac{360(o+n)}{365}\right] \cdot D_s \tag{8}$$

where the coefficient of inclination rate of change is that $k = 23.45$ the sunshine time is $o = 284$ [20],[21].

D. Remote Sensing of Solar Energy Resources by Multi-combination Methods

Based on the above analysis, the multi-combination method uses inclination, weather prediction, sunshine time, sunshine intensity and other indicators to realize the comprehensive utilization of solar energy resources, hypothesis 3: the remote sensing coefficient is k_i, the multi-combination means is y_i, the solar power generation power is Q_i, the calculation is shown in equation (9).

$$Q_i = \frac{\sqrt{\omega_i \sum_{i=1}^{n} \sigma \cdot yday \cdot D_s \cdot q_i \cdot y_i}}{k_i} \tag{9}$$

where n is the number of areas for remote sensing; In addition, the control process of solar remote sensing is as follows.

Using the diffusion partial differential equation, the only solution for the optimal insolation (4) is calculated:

$$\frac{\partial}{\partial t} \hat{f}(p) = \frac{1}{2} \cdot \frac{\partial^2}{\partial t^2} \hat{f}(p) \tag{10}$$

If and only if $h = 0$, incorporating interference factors, the calculation process is as follows.

$$\hat{f}(p) = \frac{1}{n} \sum_{i=1}^{n} \delta(p - p_i) \tag{11}$$

where : δ is the interference randomness function. Finally, the daylight intensity is collected jointly, and the acquisition function is $\kappa(p, p_i; h)$ as follows:

$$\kappa(p, p_i; h) = \sum_{k=-\infty}^{\infty} \phi(p, 2k_i + p_i |h) + \phi(p, 2k - p_i |T_i) \tag{12}$$

After the calculation is completed, the χ^2 goodness-of-fit with the historical data should be fitted with the multiple sunlight power to verify the effectiveness of the remote sensing scheme, χ^2 as shown in Eq. (13).

$$\chi^2 = \sum_{i=1}^{k} \frac{(N_i - n_i)^2}{n_i} \tag{13}$$

where: N_i is i the solar power of the first period; n_i is i the expected frequency of the first photovoltaic panel, and $n_i = m\left[\hat{F}(x_i) - \hat{F}(x_{i-1})\right]$ $\hat{F}(x_i)$ is a function of data distribution.

3. Actual Case Analysis

A. Case Introduction

This paper takes the solar matrix in area A as the research object, the matrix covers an area of 150 hectares, the number of matrix blocks is 3600 [22],[23], the polycrystalline silicon solar panel is used for photovoltaic energy reception and storage in the nickel lithium battery, of which the construction line of the solar power grid is 1032, the photovoltaic energy and power generation power are between 1KW and 2KW, the working time is 24 hours, the data collection time in this paper is 30 days, the data collection is carried out by PC, and the data statistics and analysis are carried out by Excel The results were simulated by Matlab simulation and the geographical location and solar photovoltaic energy were measured with GIS data, and the specific line construction is shown in Figure 2.

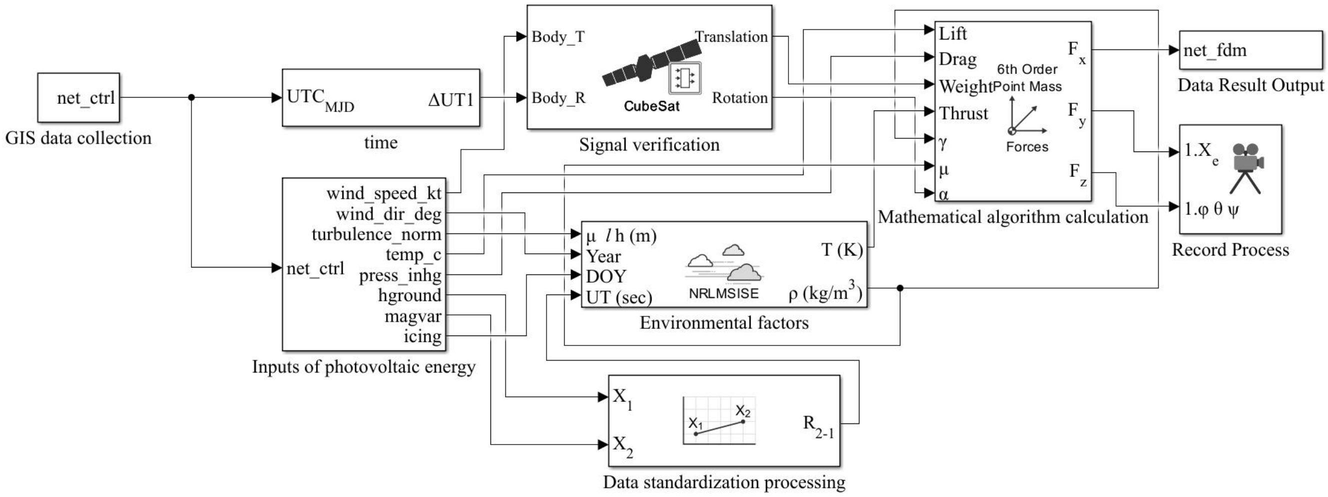
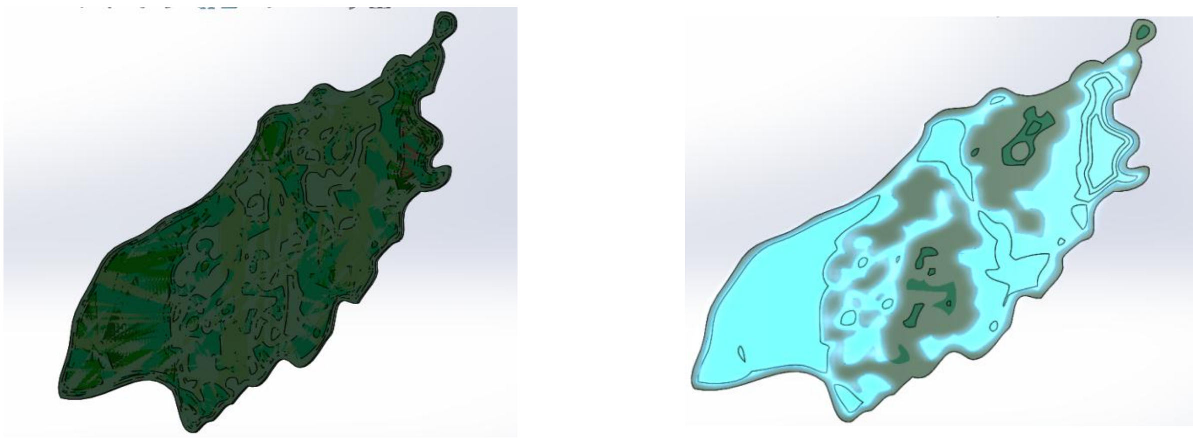


Figure 2. Building a Line Function

Through GIS information collection, 60 experimental areas in the jurisdiction of the area are used for inclination, carrier, type, meteorological parameters and other data. Among them, the control data value is between 0~1. The results show that the dispersion of the data is 0.562, indicating that there is no correlation between the data. At the same time, the eigenvalues of the data are calculated, whether the data is valid or not, and the datasets without eigenvalues are eliminated, and the number after GIS processing is shown in Figure 3.



Remote sensing area Solar energy distribution

Figure 3. Solar Energy Resources after GIS Treatment

From the data analysis in Figure 3, it can be seen that solar energy resources are mainly at the foot of the ridge and the resources are widely distributed in the whole jurisdiction, showing a trend of east, west, north and south solar energy resources do not form a central axis, so the resources are relatively scattered, and there is no concentration trend, which can be used as a later distribution and comparison.

B. Comparison of Solar Power Generation

Solar power generation is a direct result of the use of different combinations, and solar power generation is closely related to angle, inclination, weather prediction, and overall solar panel control, so the comparison of solar power generation is a key part of the study. Different methods were used for solar power generation and compared with a single measurement method, and the results are shown in Figure 4.

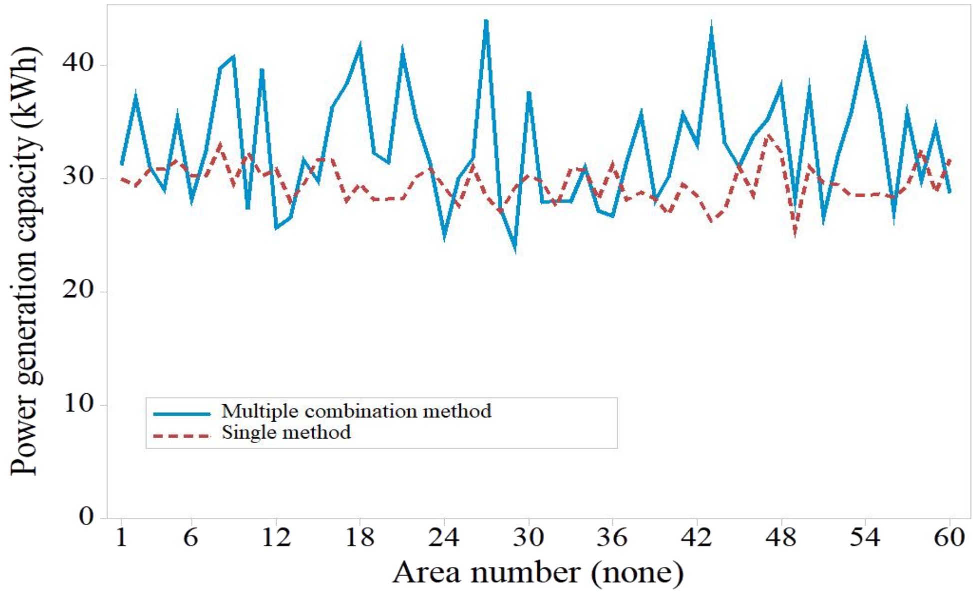


Figure 4. Comparison of Solar Power Generation in Different Regions

Through the comparison of the data in Figure 2, it is found that the multi-combination method can improve the utilization rate of solar energy resources, which is significantly better than the single-combination method. The verification of the application calculation model of solar energy resources based on the multiple combination method can determine the effective utilization of solar energy resources, so as to obtain the conversion rate of solar photons, and then calculate the power generation of solar energy and the indirect indicator carbon neutrality benefit. The extraction of high-resolution remote sensing information and the recording of the power generation of solar photovoltaic panels found that the monthly power generation was 3.14 billion kWh, and the predicted annual power generation was 33.968 billion kWh, which was converted into a CO_2 emission reduction of 266.65 tons. Taking into account factors such as mountain slopes and cloudy skies, the annual power generation capacity of shady areas such as ridges is 10.535 billion kWh, which is converted into a reduction of 161.2 tons of carbon dioxide emissions. Compared with the single method, it was found that the ratio of solar power generation increased by 1.654:1 and the annual CO_2 emission reduction was 427.851 tons. The main reason is to use the GIS green space solar angle and weather to predict and show an inclination angle of 80~90° with the sun to reduce the photon conversion rate of solar panels, reduce the cost of power generation, and increase the solar power generation per unit area. The analysis of solar power generation over time is shown in Table 1.

Table 1. Solar Energy Resource Control at Different Times

METHOD	TIME	ANGLE (°).	ELECTRICITY GENERATION (KW).	ADJUSTMENT TIME(S).
Multi-combination method	8:00~10:00	80~90	20.23	106±0.20
	11:00~14:00	80~90	20.75	- 1.02±0.23
	14:00~20:00	80~90	20.85	- 1.12±0.19
	20:00~8:00	80~90	21.63	- 1.32±0.31
Fixation method	8:00~10:00	45±0.22	18.62	-
	11:00~14:00	- 45±1.22	20.32	-
	14:00~20:00	- 45±2.12	16.53	-
	20:00~8:00	- 45±1.23	19.32	-

As can be seen from Table 1, the amount of electricity generated by solar panels in the case of fixed is fixed and the angle is fixed, and the amount of electricity generated decreases over time and the weakening of sunlight, and there is no adjustment time. GIS intelligent joystick control method can adjust the solar panel according to the angle of sunlight and ensure that its power generation is more than 20 kilowatts, and the adjustment time is less than one second, in addition, the multi-combination method can predict the weather in the region, and the solar panel can be adjusted and pre-set according to the weather and other data results, so as to increase the power generation of solar energy Ensure the stability of solar power generation [24],[25].

C. Comparison of Solar Reception Accuracy

The accuracy of solar reception was compared, and the actual received measured value was used as a test standard and verified with a single combination method, and the results are shown in Figure 5.

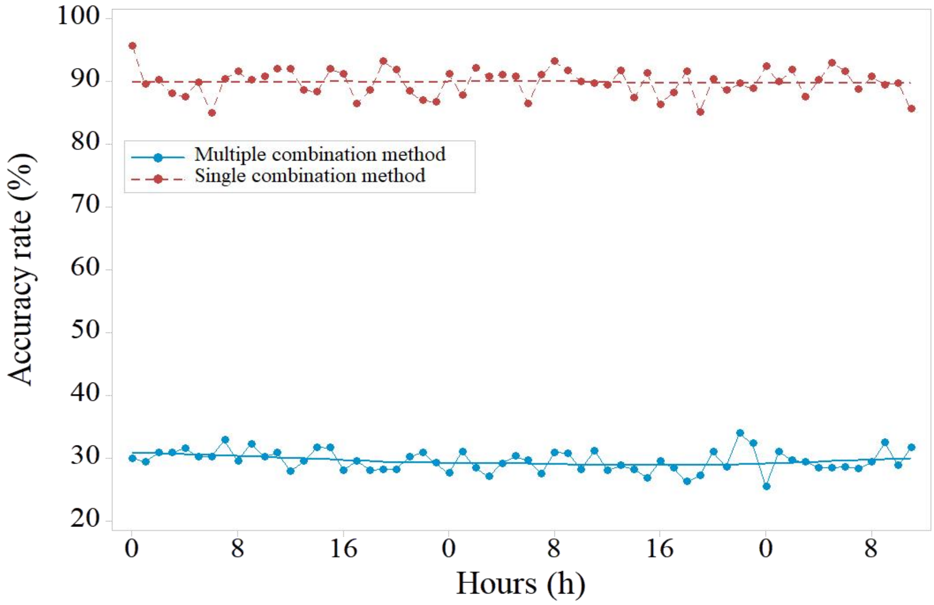
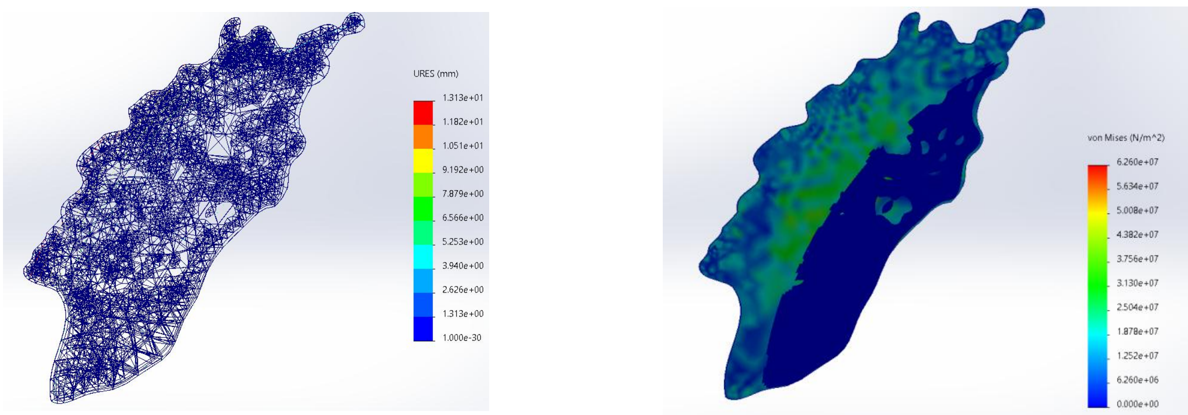


Figure 5. Accuracy of Solar Reception by Different Methods

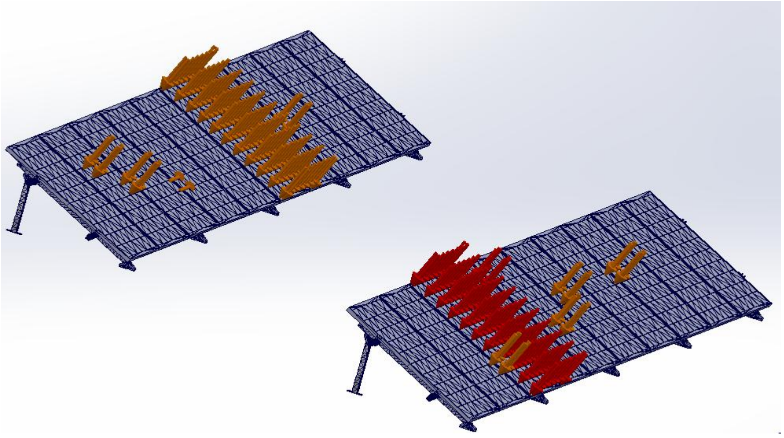
Compared with the results in Figure 5, it can be seen that the solar reception accuracy of the multi-combination method is higher, greater than 90%, which is better than that of the single-combination method. Through the smoothing line analysis, it is found that the variation amplitude of the multi-combination method is smaller, which is better than that of the single-combination method. In the application of solar energy resource application assessment, the use of inclination, type and other combination indicators can more efficiently and intuitively express the spatial distribution form and potential of regional renewable energy, more clearly define the future development plan of renewable energy, and provide auxiliary means for setting more scientific renewable energy development goals. On the basis of a single index, the multiple combination method constructs the index set and inclination angle, and combines the intelligent remote sensing system to improve the accuracy of solar angle recognition. The infrared measurement method is used to measure the power generation of the solar panel, and the results are shown in Figure 6.



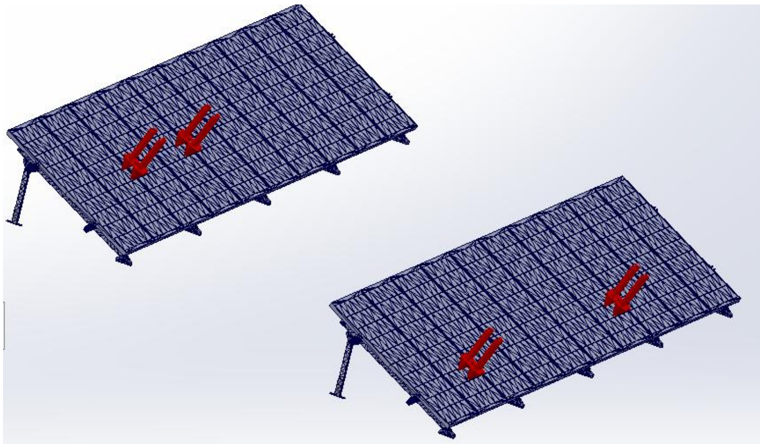
Receiving point Distribution of solar energy at the receiving point

Figure 6. Comparison of Solar Panel Power Generation in Different Regions

According to the data analysis in Figure 6, it can be seen that the power generation of solar panels is almost consistent with the infrared test results, and they are all in the northwest direction of the map. It can be seen that the multi-combination method is not affected by factors such as region and weather, and can maintain the rationality and stability of the entire natural cashmere power generation, especially the key indicators such as power flow and voltage, and can be combined with the thermal power grid to expand the scope of solar energy utilization. Moreover, the infrared measurement of the solar matrix shows that the solar energy conversion is consistent with the actual results, as follows:



The amount of solar energy obtained by the multi-combination method



The amount of solar energy obtained by a fixed method

Figure 7. The Amount of Solar Energy Obtained by Different Methods

From the data analysis in Figure 7, it can be seen that the multi-combination method obtains more sunlight, which is mainly used for angle and weather prediction, while the fixed method obtains a relatively small amount of sunlight, which also proves that the multi-combination method can effectively utilize solar energy resources.

4. Conclusion

As one of the important resources of clean energy, solar energy is mainly obtained through solar polycrystalline silicon panels, but the angle of times shows a changing trend, and is affected by many factors such as policy and weather, in fact, the collection of solar energy is relatively low, can not meet the daily changes, the need for intelligent multi-combination remote sensing methods, can remotely control the solar panels, and analyze according to the local weather forecast and fine grain characteristics, so as to adjust the angle of the solar panels, and obtain the best solar resources The results of this round of research show that the multi-group method is high in obtaining solar energy resources and stability, its accuracy reaches more than 90%, and the stability error is less than 10% And Taiwan has the adjustment time of the light panel within two seconds The overall performance is relatively good Verified by infrared scanning The combination of multiple combination methods and intelligent remote sensing technology can achieve the maximum acquisition of solar energy resources and reduce the research on solar energy resource collection on shady slopes and weather In order to improve the utilization rate of solar energy resources, a multiple combination method of carriers, inclination angle and illumination intensity was proposed, and the solar energy resources of the intelligent remote sensing system were calculated. The results show that in solar power generation, the multi-combination method is better than the single combination method, and the flat-slope power generation and flat carrier power generation are better than the single combination method. In terms of solar energy receiving accuracy, the receiving accuracy of the multi-combination method is higher than that of the single combination method, which is about 10% higher, and the acceptance rate of solar energy can be improved through the carrier, angle, intensity and other indicators, and the image advantages of intelligent remote sensing can be brought into play. At present, due to the limitations of research conditions, the accuracy verification of solar resource assessment results is mainly carried out through literature data analysis, and future PV projects and project operation data can be cross-verified, so as to further improve the evaluation accuracy of the method. In this paper, there are problems in data collection and a small number of sample points, and the above problems will be analyzed in the future.

References

[1] N. M. Abdel-Aziz, K. A. Eldrandaly, I. Abdel-Fatah, and M. Abdel-Basset, "Enhanced multiobjective optimizer for GIS-based siting of solar PV plants in Red Sea Governorate, Egypt," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 26, no. 1, pp. 161-172, 2023.

[2] H. F. Ali and S. M. Ghoneim, "Satellite-based silica mapping as an essential mineral for clean energy transition: Remote sensing mineral exploration as a climate change adaptation approach," *Journal of African Earth Sciences*, vol. 196, p. 104683, 2022.

[3] E. Arnaudo *et al.*, "A comparative evaluation of deep learning techniques for photovoltaic panel detection from aerial images," *IEEE Access*, vol. 11, pp. 47579-47594, 2023.

[4] S. Asadzadeh and C. R. Souza Filho, "Numerical modeling of land surface temperature over complex geologic terrains: A remote sensing approach," *Remote Sensing*, vol. 15, no. 19, p. 4877, 2023.

[5] A. T. Assireu *et al.*, "EOSOLAR project: Assessment of wind resources of a coastal equatorial region of Brazil—Overview and preliminary results," *Energies*, vol. 15, no. 7, p. 2319, 2022.

[6] J. Chen, Z. Shao, X. Deng, X. Huang, and C. Dang, "Vegetation as the catalyst for water circulation on global terrestrial ecosystem," *Science of the Total Environment*, vol. 895, p. 165071, 2023.

[7] Q. Chen *et al.*, "Remote sensing of photovoltaic scenarios: Techniques, applications and future directions," *Applied Energy*, vol. 333, p. 120579, 2023.

[8] R. Colombo *et al.*, "Mapping snow density through thermal inertia observations," *Remote Sensing of Environment*, vol. 284, p. 113323, 2023.

[9] P. D. DeWitt and A. G. Cocksedge, "A simple framework for maximizing camera trap detections using experimental trials," *Environmental Monitoring and Assessment*, vol. 195, no. 11, p. 1381, 2023.

[10] Z. Dui, Y. Huang, J. Pin, and Q. Gu, "Automatic detection of photovoltaic facilities from Sentinel-2 observations by the enhanced U-Net method," *Journal of Applied Remote Sensing*, vol. 17, no. 1, p. 014516, 2023.

[11] P. Dutta *et al.*, "Combining portable solar-powered centrifuge to nanoplasmonic sensing chip with smartphone reader for rheumatoid arthritis detection," *Chemical Engineering Journal*, vol. 434, p. 133864, 2022.

[12] A. H. Effat and M. A. El-Zeiny, "Geospatial modeling for selection of optimum sites for hybrid solar-wind energy in Assiut Governorate, Egypt," *Egyptian Journal of Remote Sensing and Space Sciences*, vol. 25, no. 2, pp. 627-637, 2022.

[13] B. Halder *et al.*, "Land suitability investigation for solar power plant using GIS, AHP and multi-criteria decision approach: A case of megacity Kolkata, West Bengal, India," *Sustainability*, vol. 14, no. 18, p. 11276, 2022.

[14] X. Hu *et al.*, "Evaluation of the temporal reconstruction methods for MODIS-based continuous daily actual evapotranspiration estimation," *Agricultural Water Management*, vol. 275, p. 107991, 2023.

[15] H. Jiang *et al.*, "Geospatial assessment of rooftop solar photovoltaic potential using multi-source remote sensing data," *Energy and AI*, vol. 10, p. 100185, 2022.

[16] H. Jiang *et al.*, "High-resolution analysis of rooftop photovoltaic potential based on hourly generation simulations and load profiles," *Applied Energy*, vol. 348, p. 121553, 2023.

[17] W. Jiang, B. Tian, Y. Duan, C. Chen, and Y. Hu, "Rapid mapping and spatial analysis on the distribution of photovoltaic power stations with Sentinel-1&2 images in Chinese coastal provinces," *International Journal of Applied Earth Observation and Geoinformation*, vol. 118, p. 103280, 2023.

[18] M. Muñoz-Salcedo, F. Peci-López, and F. Táboas, "An empirical correction model for remote sensing data of global horizontal irradiance in high-cloudiness-index locations," *Remote Sensing*, vol. 14, no. 21, p. 5496, 2022.

[19] A. Nassar *et al.*, "Using remote sensing to estimate scales of spatial heterogeneity to analyze evapotranspiration modeling in a natural ecosystem," *Remote Sensing*, vol. 14, no. 2, p. 372, 2022.

[20] Y. Tuncel, T. Basaklar, D. Carpenter-Graffy, and U. Ogras, "A self-sustained cps design for reliable wildfire monitoring," *ACM Transactions on Embedded Computing Systems*, vol. 22, no. 5s, pp. 1-23, 2023.

[21] L. Wang *et al.*, "Incorporation of net radiation model considering complex terrain in evapotranspiration determination with Sentinel-2 data," *Remote Sensing*, vol. 14, no. 5, p. 1191, 2022.

[22] F. Xie, H. Luo, S. Li, Y. Liu, and B. Lin, "Using clean energy satellites to interpret imagery: A satellite IoT oriented lightweight object detection framework for SAR ship detection," *Sustainability*, vol. 14, no. 15, p. 9277, 2022.

[23] G. Yatu and S. Samanta, "Modeling of potential renewable energy in Papua New Guinea: Biomass and solar energy," *Spatial Information Research*, vol. 30, no. 3, pp. 355-370, 2022.

[24] A. M. Zeyada, K. A. Al-Gaadi, E. Tola, R. Madugundu, and A. A. Alameen, "Sentinel-2 satellite imagery application to monitor soil salinity and calcium carbonate contents in agricultural fields," *Phyton-International Journal of Experimental Botany*, vol. 92, no. 5, pp. 1603-1620, 2023.

[25] Z. Zhang, Q. Wang, Z. Liu, Q. Chen, Z., Guo, and H. Zhang, "Renew mineral resource-based cities: Assessment of PV potential in coal mining subsidence areas," *Applied Energy*, vol. 329, p. 120296, 2023.