The Efficiency and Performance Detection Algorithm and System Development for Photovoltaic System through use of Thermal Image Processing Technology

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Abstract. In recent years, solar energy has become more and more popular because it is one of the renewable energy resources that are constantly replenished and will never run out. Nowadays, there are many solar panels that have been installed on the roof of residence in Taiwan. However, it does not have many convenient, secure and affordable methods to detect the effectiveness of those roof-top photovoltaic systems. Therefore, this study not only proposes the algorithms for determining the effectiveness of solar panel by using the thermal sensor, but also constructs a system to analysis the pictures that taken from thermal sensor and report the condition of solar panel automatically. Finally, we will live in a better environment by using the solar energy and the detection system with algorithms this study proposed at same time.

INTRODUCTION

In the past decade, the government on Taiwan has gradually attached great importance in seek of alternative energy resources, particularly after the Fukushima nuclear catastrophe. Therefore, the research and development of renewable energy resource technologies, such as solar, wind and water, has become the main energy policy of Taiwan government. Now, however, the land area of Taiwan is too small to be suitable for constructing large-scale grounded solar power system. Fortunately, the total potential energy generating capacity of unconventional solar systems in Taiwan, including roof-top solar systems, is 1.4 times more than other systems [1]. Thus, instead of grounded solar energy system, Taiwan government firstly attempts to develop and install roof-top type photovoltaic systems.

Unfortunately, the system maintenance of roof-top type photovoltaic system is a highly hazard mission for maintainers. Therefore, looking for a low risk and secure system detection method is necessary. Luckily, researchers have demonstrated that temperature is a significant factor to affect the energy generating efficiency of solar panels [2,3,4]. Therefore, we considered that relationships between working temperature and solar panel energy generation will be found to estimate the effectiveness of photovoltaic system. Althought, some solar system performance predication and estimation methods have been announced [6,7,12,13]. Nevertheless, using thermal image processing technology to estimate the performance for photovoltaic system is actual rare. Therefore, our algorithms and system
may be novelty and useful. Moreover, our system not only can quickly point out malfunctioned solar panel, but also be capable of improving efficiency and security for photovoltaic system maintenance.

**LITERATURE REVIEW**

K. C. Hsu et al. [5] deemed that monitoring system for solar panels is still in the earlier stage of development. He indicates that a better monitoring system is helpful for improving the usability of photovoltaic system and decrease operating costs of manufacturer. Meanwhile, recent studies have announced three similar solar energy supervise systems that included functions of wireless communication, data collection, malfunction warning and circuits of voltage, current and temperatures detection, can both enhance the efficiency of malfunctioning remove and reduce the cost of maintenance resources [6,7,8]. In addition, research results have been proven that the combination of solar panel and building structure may drop the cost of photovoltaic system installation and decrease the consumption of air condition system from approximately 9.19% to 18.28% [9,10]. Furthermore, Ho [11] invented two avant-garde systems, which are HeatProbe and ThermalProbe. These systems can assess the electricity consumption of individual person and product through use of thermal sensing technology. In addition, the accuracy of Ho's systems is around 80%. Therefore, it can probably be regarded as innovative and accurate systems.

**WEATHER DATA COMPARISON ALGORITHM**

Researchers revealed that the energy generating capacity of photovoltaic system is highly relevant to sunshine duration [4,12]. Therefore, we firstly developed an algorithm that contains a sunshine duration comparison function. It compares EXIF date data of thermal image with the weather data from Taiwan Central Weather Bureau (Taiwan CWB). Finally, the algorithm sends system the weather data comparison result and shows weather data to users.

```
Algorithm 1 Weather Data Comparison
Extract Out the Date Data from EXIF of Thermal Image
Capture Weather Data and Date Data from Taiwan Central Weather Bureau
If (EXIF Date Data is true and Weather Data from Taiwan CWB is true)
    If (Date Data from EXIF matches Date Data from Taiwan CWB)
    {Display Weather Data of Thermal Image Taken Date}
Else{Display Date Data Mismatch}
```

**THE ALGORITHM OF THERMAL IMAGE PROCESSING**

In addition, researchers verified that temperature is the main affective factor of the working efficiency of photovoltaic system [2,3,4]. Therefore, we create algorithm 2 to separate and convert coloured thermal image to grey scale image and calculate the proportion of specific colour pixels to get working temperatures of solar panels.

```
Algorithm 2 Thermal Image Processing
Import Thermal Image
Obtain Width and Height Data of Thermal Image
If (Red Colour Pixel Detection is true)
    {Convert Red Colour Pixels to White}
Else
    {Convert Colour Pixels of Blue and Green to Black}
Recalculate Colour Pixel Proportions of the New Black and White Image
Display Red Colour Pixel Proportions
```

**THE EFFICIENCY AND PERFORMANCE DETECTION ALGORITHM FOR PHOTOVOLTAIC SYS**

Algorithm 2 is designed to use red represents overheated solar panels and electricity generating failure. Hence, algorithm 2 will convert red colour pixels to white. Then, it calculates white pixels account for the percentage of
whole black and white picture to obtain the overheated proportion of solar panel. After that, algorithm 2 measures which solar panel is overheated according to the white pixel proportions. Finally, we combined algorithm 1 and algorithm 2 to build our effectiveness detection algorithm for photovoltaic system.

Algorithm 3 Efficiency and Performance Detection Algorithm for Photovoltaic System

Case A “Weather Data from Algorithm 1 is Sufficient Sunshine Duration”

{ 
  If (Current Overheated Proportions > Maximum Overheated Proportions that Set by the User) 
    {Show Text Information “Performance of PV System: Poor”} 
  Else if (Minimum Overheated Proportions that Set by the User < Current Overheated Proportions < Maximum Overheated Proportions that Set by the User) 
    {Show Text Information “Performance of PV System: Normal”} 
  Else 
    {Show Text Information “Performance of PV System: Good”} 
}

Case B “Weather Data from Algorithm 1 is Insufficient Sunshine Duration”

{Display “Detection Result Failure”}

EXIF DATA EXTRACTION AND WEATHER DATA COMPARISON

As figure 1 (a) shown, algorithm 1 allows system to compare the EXIF date data with weather data from Taiwan Central Weather Bureau at the same time. Therefore, we can confirm that the photovoltaic system is working in correct temperature condition by reviewing weather data comparison result as figure 1 (b) shown.

THE CALCULATION OF COLOUR PIXEL PROPORTIONS AND WORKING PERFORMANCE CHECK

In order to calculate specific colour pixel proportions of thermal image, our system exploits algorithm 2 to convert red colour pixels to white colour pixels. Therefore, our system can calculate the proportions of white pixels to estimate the effectiveness of solar panels as figure 1 (c) shown. Finally, the system will show the performance checking status of photovoltaic system as figure 1 (d) shown.

FIGURE 1. (a) shows the EXIF date data extraction function. (b) reveals the weather data comparison function of our system. (c) shows the calculation result of colour pixel proportions. (d) represents the performance checking status of photovoltaic system.

In consideration of the material property of numerous photovoltaic systems, our system allows user to enter such parameters as working temperatures and overheated proportions, to be the system evaluation standard. Then, we build the efficiency and performance detection system for photovoltaic system as figure 2 shown.

FIGURE 2. The Interface of our Efficiency and Performance Detection System
System Test Results

**TABLE 1.** Test Results of the Efficiency and Performance Detection System

<table>
<thead>
<tr>
<th>Missions</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
</tr>
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<tbody>
<tr>
<td>Weather Data Comparison</td>
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</tr>
<tr>
<td>Colour Conversion: RGB to Grey</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Calculate Colour Pixel Proportions</td>
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<tr>
<td>System Performance Status Check</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>System Performance Status Display</td>
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<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>

**CONCLUSION**

According to system test results showed that all functions of our system worked perfectly. Thus, applying thermal image identification technology to the performance estimation of photovoltaic system may be actual effective. Meanwhile, our method has three advantages, containing affordable costs, highly accuracy and secure. In addition, it can enhance the maintenance efficiency and reduce the hazard potential for photovoltaic system maintainers when they are working. Furthermore, this method can provide its contribution for the working effectiveness estimation of photovoltaic system.

**REFERENCES**

11. B. J. Ho, “Thermal Sensing for Metering Per-Appliance and Per-User Power Usage”, Master thesis, National Taiwan University, 2012