Application of Fuzzy Theory in the Decision of Solar PV System Design

Shih-Wen Hsiao and Teng-Chin Yu

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Shih-Wen Hsiao
Department of Industrial Design
National Cheng Kung University
Tainan, Taiwan
swhsiao@mail.ncku.edu.tw

Teng-Chin Yu
Department of Industrial Design
National Cheng Kung University
Tainan, Taiwan
rexyu1024@yahoo.com.tw

***Abstract*—The research mainly took "Sunshine Public House" which was in the promotion plan of Tainan municipal government to develop renewable energy as the research object. The purpose of this study was to introduce the application of concurrent engineering method in the design of solar photoelectric system, and the Fuzzy theory was used to achieve closeness in the design decision analysis. In this study, the optimal design decision was verified through cross-comparison of practical examples, and then the project management standard was established by resulting design process. The project management standard was applied to the design of solar PV system below 100kW. In order to significantly shorten the construction process of the project and reduce the failure factors. The research results confirmed that introducing concurrent engineering and the fuzzy theory closeness in the study of the project development process of the solar PV system can complete the most effective construction and the most effective design decisions in the shortest time. Thus, the perfect solar PV system products which were high quality, highly efficient, low cost, long- lasting were achieved.**

Keywords—Concurrent engineering , Solar, Target tree, Fuzzy theory

I. INTRODUCTION

The impact of global warming on the environment has been become increasingly significant. In order to get rid of the impact of greenhouse effect and reduce carbon dioxide emissions, countries have begun to seek a new generation of energy to replace traditional fossil fuels. Since 1992, a wholesale power policy for solar PV system had established by government for power companies in the United States, Japan, Europe and other regions cooperating with civil societies to purchase surplus power from solar PV system, and effectively alleviated the shortage of power supply at peak times. The Energy Bureau of the Ministry of Economic Affairs in Taiwan had promoted the plan of "one million solar roofs", which was scheduled to complete the settings of 847MW solar photovoltaic power generation systems in 2015, and to reach the settings of 2,120MW solar photovoltaic power generation systems in 2020. The aim of the 2030 was to reach the settings of 6,200MW solar photovoltaic power generation systems [1].

It is either scorching hot or bitterly cold in the solar system of Earth. In fact, Earth's surface has relatively mild and stable temperatures where human beings can live comfortably under the given condition. However, ninety-seven percent of the climate scientists agree that mankind have changed Earth's atmosphere in dramatic ways over the past two centuries, resulting in global warming. To understand and solve the problem of global warming, it is necessary to first examine greenhouse effect and ways to its further improvement [2].

In addition, the government also wanted to boost the overall confidence of the solar photovoltaic industry . The target of solar photovoltaic setting planning in 2013 would be increased from 100MW to 130MW to establish the domestic setting achievements, and achieved multiple benefits such as industrial and environmental [3]. The strategy of "first slow, then fast, first roof and then ground" was adopted in the plan of "one million solar roofs". In the future, with the cost of solar photovoltaic power generation falling year by year, the annual driving capacity would increase year by year . Finally , the setting goal of popularizing every household would be reached [4]. The study would take the "Sunshine Public House" plan which was in the "Green power city in Tainan " plan of the promotion plan of renewable energy development as the research object. In the design of solar PV system, concurrent engineering was used to analyze the most appropriate design process, and then the fuzzy theory was applied to the design decision analysis to obtain the best decision results [5].The resulting design process was generated to establish the project management standards [6].

II. RESEARCH METHOD

In this study, "Application for Solar Optoelectronics Sales Process" published by the ministry of economic affairs and Taiwan electric power company was as the research principal axis, connecting the construction design process and specification of solar PV system to design questionnaires.

Using the research method of the fuzzy theory to find out the optimize design. Then, the concurrent engineering process was applied for design planning, including the design of the team, automation process, manufacturing technology, laws and regulations, and so on. Finally, an information sharing working platform could be provided, enabling the project team leader to have sufficient information when the solar PV system project was developed [7]. In addition, all requirements and quality elements in the whole system construction stage can be considered at the same time. It was expected to accelerate the progress of the design development project, improving the accuracy of the system design. The development cost and the failure rate of the construction would be reduced.

In the design of the traditional solar PV system, most designers usually took the rule of thumb design planning concepts to carry out the rough design principles, which often resulted in many errors in the solar PV system from the design stage to the implementation stage [8]. This process was regarded as a black-box operation. After many interviews with experts, the study summarized the mistakes often made by solar PV system designers. In order to solve the unpredictable environment variables and design blind spot, the black-box operation analysis was as the direction of design thinking, and the design specifications of the solar PV system were proposed, as shown in Table 1.

TABLE I. THE DESIGN SPECIFICATIONS

Order Need Description

Environmental factor	1.	D	Sunshine amount over 3 hours for ESH.
	2.	W	The photovoltaic panel faces the south.
	3.	W	The degree of the photovoltaic panel is 23.5 degrees.
	4.	D	No shading area condition on site.
	5.	W	BIPV (Building -integrated photovoltaics).
Safety factor	1.	W	Good structural strength.
	2.	W	The converter is not available for rain.
	3.	D	Circuit line must comply with electrical regulations.
	4.	W	The support frame should have a life of more than 20 years.
	5.	D	Wire insulation must comply with outdoor regulations.
Efficiency conversion factor	1.	D	Wire insulation resistance must be greater than 1 MG.
	2.	W	The photoelectric system will operate normally within 5 years.
	3.	W	It has an instant monitoring system .
	4.	D	The power generation system RA is more than 80%.

***D is the necessary demand / W is the ideal demand**

According to the above black-box design process analysis, the target tree model was set up, as shown in Figure 1. This target tree can be divided into three important factors: environmental factor, safety factor and efficiency conversion factor, and the main factors of each important factor are listed [9]. Then, the weight of each design is 0.5 for environmental factor (W1), 0.3 for safety factor (W2) and 0.2 for efficiency conversion factor (W3), as shown in Table 2.

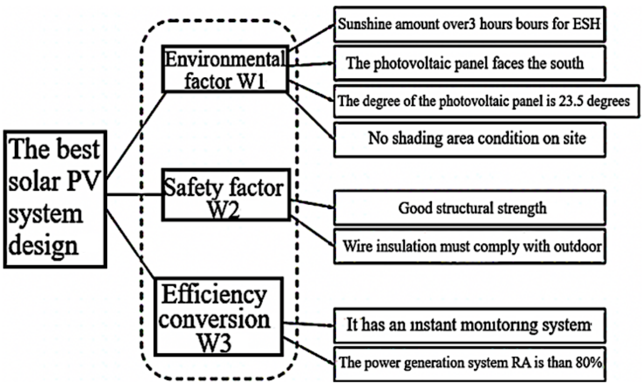

Fig. 1. A target tree of the solar PV system

TABLE II. THE DESIGN LIST METHODS

Environmental factor	1	3	4	8	**(W1)**
Safety factor	1	1	2	4	**(W2)**
Efficiency conversion factor	0	2	1	3	**(W3)**
Sum				15	

The weight matrix can be obtained by combining all the above policy weights, as shown in Table 3.

TABLE III. THE WEIGHT MATRIX

Environmental factor W1	**0.5**
Safety factor W2	**0.3**
Efficiency conversion factor X3	**0.2**

In this study, the Nan-an elementary school in Tainan was taken as an example. The solar PV power generation demonstration system can not only the application of solar photovoltaic efficiency, but also have the education function of solar photovoltaic knowledge, which was complementary to customers, visiting groups and communities. Firstly, the environmental status was analyzed, and then the design planning and shading simulation work were conducted according to GOOGLE MAP and SKETCH UP. The designed site C and site B are as shown in Figure 2.

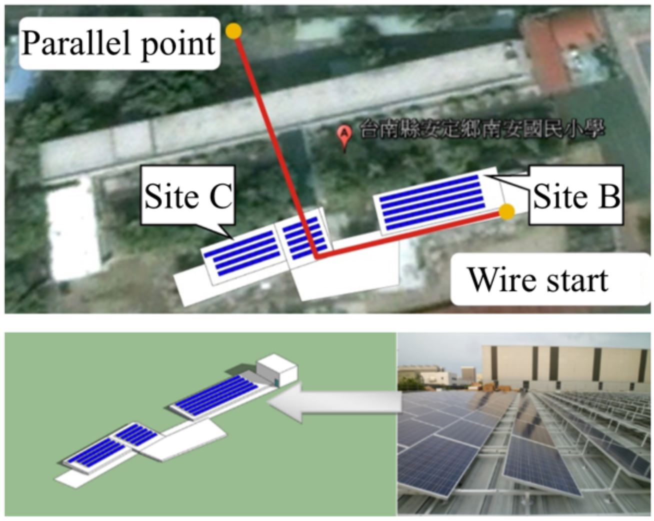

Fig. 2. Solar photovoltaic set the whole area configuration map

In the study, the questionnaire survey was used to collect the satisfaction degree of different subjects to different design sites. Five solar PV system designers with more than 7 years of work qualification were invited as subjects. The questionnaire was designed according to the design criteria of target tree. The five vocabulary scales (very dissatisfied, not satisfied, the common, satisfied and very satisfied) were collected to establish the fuzzy membership function.

The information of three sites were studied and compared. It was assumed that the site A was the best standard for the solar PV system set by the industrial research institute. Therefore, the scale of very satisfied was as the standard value. The satisfaction fuzzy possibility of site B and site C can be collected respectively, as Table 3 shows. In addition, the fuzzy sets of site A, B and C were obtained according to the field evaluation, as shown in Table 4.

TABLE IV. THE FUZZY POSSIBILITY

Site B	ID 1	ID 2	ID 3	ID 4	ID 5	Average
Environmental factor X1	0.5	0.75	1	0.75	0.75	0.75

Safety factor X2	0.75	0.5	1	0.75	0.5	0.7
Efficiency conversion factor X3	0.75	0.75	0.75	0.75	0.5	0.7
Site C	**ID 1**	**ID 2**	**ID 3**	**ID 4**	**ID 5**	**Average**
Environmental factor X1	0.5	0.5	0.75	0.25	0.5	0.5
Safety factor X2	0.25	0.25	0.5	0.5	0.25	0.35
Efficiency conversion factor X3	0.5	0.75	0.75	0.75	0.5	0.65

TABLE V. THE FUSSY SETS

Site A	1	1	1
Site B	0.75	0.75	0.7
Site C	0.5	0.35	0.65

The result of The normalized weight coefficients W (xi) were 1.5, 0.9, 0.6 (environmental factor, safety factor, efficiency conversion factor). We applied Hamming closeness to close, and used W (i) weight instead of 1/n= (1/3) (Formula 1-2).

$$NH(\tilde{A},\tilde{B})=1-\sum_{i=1}^{3} W(\mathrm{xi})\left|\eta\tilde{A}(xi)-\eta\tilde{B}(xi)\right|= 0.175 \quad (1)$$

$$NH(\tilde{A},\tilde{C})=1-\sum_{i=1}^{3} W(\mathrm{xi})\left|\eta\tilde{A}(xi)-\eta\tilde{C}(xi)\right|=-0.545 \quad (2)$$

The field B was superior to the site C according to the formula 2-3, but because NH (Ã, C) showed a negative value, we used the Wang-Liu closeness to carry on the closeness verification analysis (Equation 3-4).

$$NH\ (\tilde{A},\tilde{B})=\frac{1}{2}\left[\tilde{A}\cap\tilde{B}+(1-\tilde{A}\cup\tilde{B})\right]=0.375 \quad (3)$$

$$NH\ (\tilde{A},\tilde{C})=\frac{1}{2}\left[\tilde{A}\cap\tilde{C}+(1-\ \tilde{A}\cup\tilde{C})\right]=0.325 \quad (4)$$

The field B was superior to the site C by the formula 3-4, so the Wang-Liu closeness was more suitable for the solar photovoltaic designers to perform the differential analysis.

In this study, five solar system designers with over seven years' working experience were investigated by the methods of case data acquisition, including data collection method, interview method and field observation method. The study took Nan-an elementary school in Tainan city as an example.

Data collection method — the cases select in this study were classified basically, and the construction area, construction capacity, construction orientation and construction method are as the information which will be examined in the future.

Interview method — interview case related personnel to know the various problems and faced difficulties, and verify the feasibility of concurrent engineering system design based on the interview results.

Field observation method — the investigation of the usage current situation can be achieved based on the information of the current status of the solar PV system built by each school. The in-depth understanding of cases can be as evidence for the reasoning of the study. As shown in Table 5, according to the sum scores of these methods, the experienced solar system designers indicated that the design method of the study was indeed superior to the traditional solar system design methods.

III. Conclusion

The results of this study proved that the design and development of the solar PV systems need team work, which must be combined with designers, electromechanical technicians, civil engineers, structural technicians, maintenance engineers, business, procurement and downstream manufacturers. The concurrent engineering system and fuzzy theory closeness were applied to integrate quality, cost, construction process and usage requirements to form a complete planning design, which could reduce costs, shorten project timelines, improve engineering efficiency, and reduce wrong assessment of the sites.

The solar PV systems that applying the concurrent engineering system claim that the electronic normalization of the future possible design blueprints problems should be proceeded at the beginning of the design. Therefore, the construction in each stage of the process is different from the traditional methods. The development of the traditional engineering design process used black-box operation. Not only relevant information is not clear, but more miscalculation or design mistakes could be generated.

It is easy to cause the discontinuity of the design of the solar PV system and construction problems at the end or during construction in the original spread design conditions and the vague standardization of the definition. It not only consumes a lot of manpower and material resources, but also often leads to delay in aging and so on.

The study can analyze the demand of solar PV system construction in a more objective and detailed way to enhance the competitiveness of power generation system through the application of the fuzzy theory. Furthermore, the different stages' flow and methods of the development of solar PV system were integrated, such as the front research target tree decision, the fuzzy theory closeness evaluation, the concurrent engineering system specification, and the field investigation verification method, and so on. In the way, the rationality and stability of the solar PV system design could be improved to reduce the cost of the project, to control project quality, to increase long-term maintenance stability of the solar PV system [10].

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