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Decision framework of photovoltaic module selection under interval-valued intuitionistic fuzzy environment

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ABSTRACT

The selection of appropriate photovoltaic module is of extremely high importance for the solar power station project; however the comprehensive problem of evaluation index system, the information loss problem and the lack-objectivity problem in the selection process will decrease the reasonability of the selection result. The innovation points of this paper are as follows: first, the comprehensive evaluation index system of photovoltaic module is established from the engineering management and supply chain management perspectives to solve the comprehensive problem; second, the interval-valued intuitionistic fuzzy set (IVIFS) are introduced into the photovoltaic modules selection process to express the alternatives' performances to solve the information loss problem; third, the IVIFS entropy weight method is applied to improve the objectivity of the criteria's weights. According to the aforementioned solutions, the decision framework of photovoltaic module selection under interval-valued intuitionistic fuzzy environment are established and used in a case study to demonstrate its effectiveness. Therefore, from the theoretical modeling and empirical demonstration, the decision framework proposed in this paper can effectively handle such a complicated problem and lead to an outstanding result.

1. Introduction

Electricity is a critical infrastructure for China's economic development and the most electric power comes from the fossil-based electricity generation station. However the global warming and climate change have forced people shifted their focus of industrial development towards low-carbon renewable energy. Hence, many researchers have focus on this area, for example, Zhang et al. [1,2] studied the relationship of electricity and climate change and the energy system transition from fossil-based electricity production to near-zero emission energy, some studies focus on energy based carbon emissions, such as Ma et al. [3] studied the energy consumption and carbon emissions in a coastal city in China. The obvious conclusions of those researches are that low-carbon renewable energy can reduce the pollutants and carbon emission, and reduce environmental and climatic risks. The solar energy is no-carbon renewable energy, so establishing the photovoltaic power station is a good choice to replace the part of traditional fossil-based electricity generation station.

The photovoltaic power station project's success depends on the appropriate photovoltaic module selection, which is of extremely high importance as the costs of photovoltaic modules amount to 41.25–54% of the total cost for photovoltaic power station projects.

For the study of photovoltaic module, most researchers concern on its performances on different environments, such as Klugmann-Radziemska [4] studied the degradation of electrical performance of a crystalline photovoltaic module due to dust deposition in northern Poland, Kempe et al. [5] evaluatedthe moisture ingress from the perimeter of photovoltaic modules, Herrero et al. [6]used the module optical analyzer to evaluate the misalignments within a concentrator photovoltaic module in order to study the concerning temperature effects on the module performance, Chitti et al. [7] analyzedthephotovoltaic Module during Partial Shading based on Simplified Two-Diode Model. However, for the photovoltaic module selection problem, only a few researches have concerned on this problem, such as Kuthanazhi et al. [8] used the analytical hierarchy process (AHP) to select the photovoltaic modules for off-grid rural application, Yong et al. [9] used the Delphi method and AHP to select key technologies for the silicon photovoltaic industry in China, Abdelhamid et al. use the quality function deployment (QFD) and the AHP to evaluate the On-Board photovoltaic modules options for electric vehicles.

Based on the aforementioned researches, it is known that the study of photovoltaic module selection for the photovoltaic power station project is few and the photovoltaic module selection is the

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Nomenclature

$X = \{x_1, x_2, \ldots, x_m\}$	is a finite universal set
x_j	is the j-th element in X
D	is an IVIFS in X
$\tilde{\mu}_D(x_j)$	is the intervals of the degree of membership
$\tilde{\upsilon}_D(x_j)$	is the intervals of the degree of non-membership
$\mu_D^L(x_j)$	is the lower bound of $\tilde{\mu}_D(x_j)$
$\mu_D^U(x_j)$	is the upper bound of $\tilde{\mu}_D(x_j)$
$\upsilon_D^L(x_j)$	is the lower bound of $\tilde{\upsilon}_D(x_j)$
$\upsilon_D^U(x_j)$	is the upper bound of $\tilde{\upsilon}_D(x_j)$
$\bar{\mu}_{ij}^L$	is the weighted lower bound of membership degree of the j-th alternative on the i-th criterion
$\bar{\mu}_{ij}^U$	is the weighted upper bound of membership degree of the j-th alternative on the i-th criterion
$\bar{v}_{ij}^L$	is the weighted lower bound of non-membership degree of the j-th alternative on the i-th criterion
$\bar{v}_{ij}^U$	is the weighted upper bound of non-membership degree of the j-th alternative on the i-th criterion
μ_i^{L+}	is the maximum lower bound of membership degree of the alternatives on the i-th criterion
μ_i^{U+}	is the maximum upper bound of membership degree of the alternatives on the i-th criterion
υ_i^{L+}	is the maximum lower bound of non-membership degree of the alternatives on the i-th criterion
υ_i^{U+}	is the maximum upper bound of non-membership degree of the alternatives on the i-th criterion
μ_i^{L-}	is the minimum lower bound of membership degree of the alternatives on the i-th criterion
μ_i^{U-}	is the minimum upper bound of membership degree of the alternatives on the i-th criterion
υ_i^{L-}	is the minimum lower bound of non-membership degree of the alternatives on the i-th criterion
υ_i^{U-}	is the minimum upper bound of non-membership degree of the alternatives on the i-th criterion
$\bar{\pi}_{ij}^L$	is the weighted lower bound of hesitancy degree of the j-th alternative on the i-th criterion
$\bar{\pi}_{ij}^U$	is the weighted upper bound of hesitancy degree of the j-th alternative on the i-th criterion
π_i^{L+}	is the maximum lower bound of hesitancy degree of the alternatives on the i-th criterion
π_i^{U+}	is the maximum upper bound of hesitancy degree of the alternatives on the i-th criterion
π_i^{L-}	is the minimum lower bound of hesitancy degree of the alternatives on the i-th criterion
π_i^{U-}	is the minimum upper bound of hesitancy degree of the alternatives on the i-th criterion
A and B	are two interval-valued intuitionistic fuzzy numbers
λ	is the arbitrary real number
$M(A)$	is the score function of an interval-valued intuitionistic fuzzy number A
$\Delta(A)$	is the accuracy function of an interval-valued intuitionistic fuzzy number A
$E(A)$	is the entropy of an interval-valued intuitionistic fuzzy number A
d_{ij}	is the performance numerical value of the j-th alternative on the i-th criterion
$d_i^{\max}$	is the maximum performance numerical value of alternatives on the i-th criterion
$d_i^{\min}$	is the minimum performance numerical value of alternatives on the i-th criterion
Ω_b	is the set of benefit criteria
Ω_c	is the set of cost criteria
α	is the satisfaction expectation parameter of the benefit criteria
δ	is the satisfaction expectation parameter of cost criteria
β	is the non-satisfaction expectation parameter of the benefit criteria
γ	is the non-satisfaction expectation parameter of the cost criteria
id	is the important degree
w^s	is the subjective weight
w^o	is the objective weight
w^c	is the combination weight
a	is the combination parameter
S_j	is the j-th alternative photovoltaic module
S^+	is the interval-valued intuitionistic fuzzy positive ideal solution
S^-	is the interval-valued intuitionistic fuzzy negative ideal solution
$IVIFSD(S_j, S^+)$	is the interval-valued intuitionistic fuzzy Euclidean distances of the j-th alternative from the interval-valued intuitionistic fuzzy positive ideal solution
$IVIFSD(S_j, S^-)$	is the interval-valued intuitionistic fuzzy Euclidean distances of the j-th alternative from interval-valued intuitionistic fuzzy negative ideal solution
ρ_j	is the relative closeness degrees of the j-th alternative

multi-criteria decision making (MCDM) problem, need the appropriate MCDM methods, such as AHP. So the evaluation index system and MCDM method is very important for the photovoltaic module. However, there are some problems will decrease evaluation quality of photovoltaic module in reality.

The first problem is that the evaluation index system of photovoltaic module cannot reflect the true demands of investors. The most of photovoltaic module evaluations are only considered from the perspective of engineering management, namely, quality, cost and so on. However, the investors consider more about the reputation and after-sale service of the suppliers at the condition of the same technological level. So the photovoltaic module suppliers' conditions must be considered in the evaluation indices system, such as reputation, operational condition, production capacity, after-sale service and so on.

The second problem is the information loss. The real number and fuzzy set theory (FST) used to express the alternative's performance values cannot reflect a well-known psychological fact that the linguistic negation is not always identified with the logical negation. For example, assume that one person use the fuzzy number A to express the satisfaction degree $t_A(car) \in [0,1]$ of a car and a non-satisfaction degree automatically is equal to $1 - t_A(car)$ in logically. However, if we let the same person use Fuzzy number B to express the non-satisfaction degree $t_B(car) \in [0,1]$ of the car directly, then we will find $t_A(car) + t_B(car) \neq 1$.

The third problem is the lack of objectivity of the criteria's weights. The most used weighting methods are subjective weighting methods which calculate the criteria's weights mainly based on the human beings' intuition, such as AHP and fuzzy AHP. The weights only reflect the experts' experiences and judgment and the reasonability of weights varied with the different expertise levels.

The aim of this research is first to identify the comprehensive evaluation index system related to the photovoltaic module selec-