2016 7th International Conference on Biology, Environment and Chemistry
Volume 98 of IPCBEE (2016)
DOI: 10.7763/IPCBEE. 2016. V98. 4

An Interval-Stochastic Programming Model for Distributed Photovoltaic Power Management under Uncertainty

Ronghua Xu [1] and Yanpeng Cai [1, 2, 3 +]

[1] State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing, China

[2] Beijing Engineering Research Center for Watershed Environmental Restoration and Integrated Ecological Regulation, School of Environment, Beijing Normal University, Beijing, China

[3] Key Laboratory of Wetland Ecology and Vegetation Restoration, Northeast Normal University, Changchun, China

Abstract. In this study, an interval-stochastic programming model was formed for identifying optimal distributed photovoltaic development planning with limited subsidies under uncertainties. The model was formulated through incorporating interval and stochastic into a general optimization framework. It can deal with uncertainties expressed as both probability distributions and intervals. A solution method was proposed to solve this problem. The proposed model was then applied to a hypothetical case of planning future capacity of distributed photovoltaic power generation in three regions of China where solar energy resources and proportion of electricity consumption were full of uncertainties. Interval solutions with different electricity generation patterns were obtained. The results could be used for generating decision alternatives for helping decision-makers to identify optimal capacity allocation scheme under limited subsidies, available rooftop and grid access constraints.

Keywords: distributed photovoltaic power, subsidy, electricity, uncertainty; planning.

1. Introduction

With the growth of economy and enhancement of human activities, energy is playing an increasingly significant role in our world [1]. Traditional fossil energy resources like coal, petroleum and natural gas accounted for a very large proportion of the total energy use in many countries, especially for developing countries [2], [3]. Meanwhile, due to increasing population and rapid expansion of industry, the increasing energy consumption result in much serious energy depletion and environmental pollution [4], [5]. Consequently, it becomes more and more crucial to utilize renewable energy resources (i.e. solar power, wind power and geothermal energy) which are beneficial to environment and sustainable development [6]. In addition, application and development of renewable energy for electric power have also aroused increasingly concerns all around the world [7], [8]. As an important part of clean energy to cope with the challenge of fossil fuel depletion, solar power has been developed rapidly.

Distributed photovoltaic power generation is defined as in particularly constructed in the vicinity of the user site, which introducing user self-sufficiency and surplus electricity connected to the grid. It is a photovoltaic power generation facilities which can balance the electricity distribution system. Distributed photovoltaic power generation has some advantages: a) it has enormous environmental protection benefit with scarcely pollution (i.e. without noise, air pollution or water pollution), b) it can alleviate the situation of electricity shortages in the local system to some degree, and c) electricity generation and electricity consumption will be present in one system. In addition, distributed photovoltaic systems which connected to

+ Corresponding author. Tel.: +86(10)5880-0830; fax: +86(10)5880-2756.
E-mail address: yanpeng.cai@bnu.edu.cn.

the grid can be installed to furnish energy to a specific consumer or directly to the grid, increasing reliability of the systems [9].

Photovoltaic power generation technology was originated from Europe. Photovoltaic power generation technology can make fully use of local solar power resource with less conventional energy sources consumption. For a long time, Europe sat at the heart of the global photovoltaic market where Germany, Italy and Spain mainly accounted for a large proportion in the past. In recent years, with rapid increasing photovoltaic modules of China, Japan, the United States and other countries, the core areas of the global photovoltaic market gradually transfer from Europe to the outwards. Utilization of renewable energy resources is essential for many countries across the world particularly for developing countries [10], [11]. In recent years, solar power which is an important clean energy has been developed in electric generation. Recently, distributed photovoltaic power has been gradually developed in China. However, Photovoltaic industry in China has suffered from many difficulties during development as it is still in its infancy. Large-scale production and application of photovoltaic industry is from 2004. At the same time, due to the high photovoltaic power generation efficiency, energy conservation and government powerful support, the capacity of photovoltaic power increase rapidly lately. From 2012 to 2015, the correspondingly compound annual growth rate is 88.00% (Fig. 1).

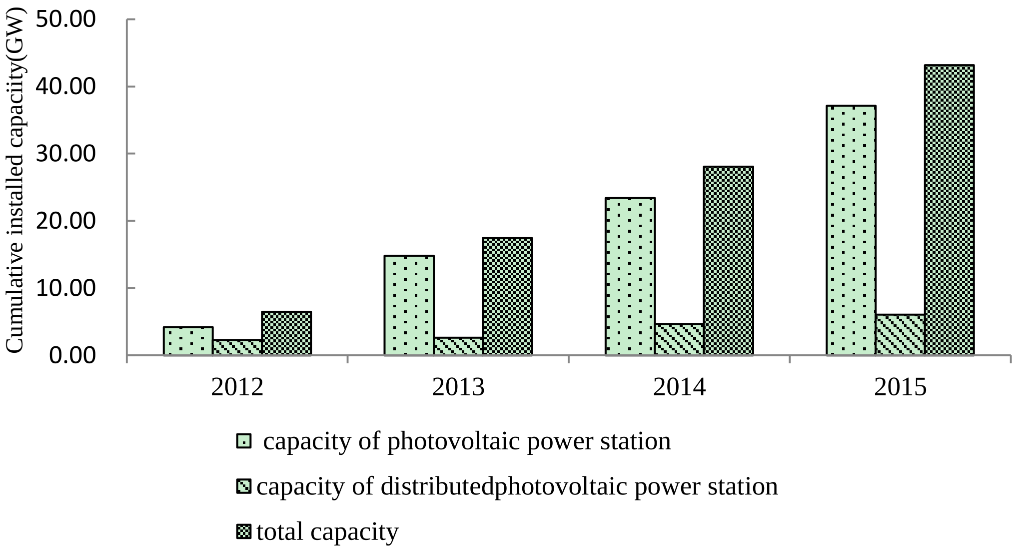

Fig. 1: Cumulative installed capacity of photovoltaic power in China (source: NEA [12])

In America, the policy of tax privilege incentives and Renewable Portfolio Standard (RPS) was introduced, and the government's financial subsidy is a crucial factor for the development of photovoltaic power. In Germany, the policy of feed-in tariffs which could subsidize photovoltaic power generation was implemented [9]. Similarly, in China, the government has been subsidizing distributed photovoltaic generation at 0.42 RMB per kilowatt hour. In China, decision-makers are facing difficulties of allocating distributed photovoltaic station quota with limited subsidies under multiple uncertainties.

Therefore, the objective of this research aims to form an interval-stochastic programming model for distributed photovoltaic power generation planning, through integrating the interval programming and stochastic programming into the general interval linear programming (ILP) framework, tackling the multiple uncertainties and complexities expressed as interval numbers and distribution information. In addition, various levels of electricity demand, self-consumed electricity ratio as well as solar power resources can be incorporated into the developed model. A case study will be provided for demonstrating applicability of the developed model. In detail, this study will (a) formulate an inexact interval-stochastic model which can reflect uncertainties expressed as intervals and probability distributions, (b) apply the model to support for planning distributed photovoltaic power generation, and (c) analyse the generated results and discuss the applicability of the developed model.

2. Methodology

2.1. Model Development

In distributed photovoltaic power planning, a manager will face problems as programming the electric power generation to generate the maximum benefits. Such a problem can be formulated as maximizing the economic benefits under limited financial allowances. In this process, multiple uncertainties may exist, such as solar power resources, self-consumed electricity ratio and available rooftop area.

The objective is to achieve optimal planning of distributed photovoltaic power generation with a maximized system benefits. The amount of electricity generation in the region is uncertain (expressed as random variable), while a plan for the allowable electricity generation levels must be made before the realization of the random variable. Therefore, the problem under consideration can be formulated as an interval stochastic programming model. The model is based on the assumption that a) initial investment are the same, b) generated electric power will be fully used, c) high quality rooftop will be considered firstly, and d) all the system efficiency of distributed PV power will be a constant. Thus the model can be formulated as follows:

$$\begin{aligned} Max\ f =&\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha \mathrm{L}_k W_{ik} H_{ik}(S_{ik}+A_{ik})E[M_{ik}]+\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha \mathrm{L}_k W_{ik} H_{ik}(N_{ik}+A_{ik})(E[1-M_{ik}]) \\ &-\sum_{i=1}^{I}\sum_{k=1}^{K}\mathrm{L}_k W_{ik} R_{ik}+\sum_{i=1}^{I}\sum_{k=1}^{K}\alpha \mathrm{L}_k W_{ik} H_{ik} BC_{ik} \end{aligned} \tag{1a}$$

subject to:

financial subsidies constraints,

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} H_{ik} \le T_{ik}, \forall\ i,k \tag{1b}$$

capacity constraints,

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \ge D_i/100, \forall\ i,k \tag{1c}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \le D_i/30, \forall\ i,k \tag{1d}$$

$$W_{ik} \ge D_i/100, \forall\ i,k \tag{1e}$$

$$W_{ik} \le D_i/30, \forall\ i,k \tag{1f}$$

demand constraints，

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \le J_i, \forall\ i,k \tag{1g}$$

Where f = economic benefit of all regions (RMB); i = the name of region; k = the time period; W_{ik} = capacity of region i in k period (MW); H_{ik} = annual utilization hours of solar power (hour); α = efficiency of system; S_{ik} = electricity price(RMB); A_{ik} = allowance of electricity price(RMB); M_{ik} = self-consumed electricity ratio; N_{ik} = Pool purchase price; E [ ] = the expected value of a random variable; R_{ik} = running costs (RMB/MW); B = 0.997kg CO_2/ kwh; C_{ik} = carbon price(RMB/kg); T_{ik} = total subsidies of electricity power(kwh); I_i = available roof area(m^2); D_i =installed capacity on roof (MW) J_i = accessible capacity of power grid(MW); k = the length of time period (year);

Let each self-consumed electricity ratio take a value M_{ikh} with the probability p_{kh} (for h = 1, 2, …, H), where h is denoted as the level of electricity demand. Thus, we have:

$$E\left[M_{ik}\right] = \sum_{h=1}^{H} p_{kh} M_{ikh},\ \forall\ i,k,h \tag{2}$$

$$E\left[1-M_{ik}\right] = \sum_{h=1}^{H} p_{kh}(1-M_{ikh}),\ \forall\ i,k,h \tag{3}$$

$$D_i = 100(\mathrm{W/m^2})*\mathrm{I}_i\ /1000000\ (\mathrm{W/MW}) \tag{4}$$

$$Max\ f = \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik} H_{ik}(S_{ik}+A_{ik})P_{kh}M_{ikh} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik} H_{ik}(N_{ik}+A_{ik})P_{kh}(1-M_{ikh}) - \sum_{i=1}^{I}\sum_{k=1}^{K} L_k W_{ik} R_{ik} + \sum_{i=1}^{I}\sum_{k=1}^{K}\alpha L_k W_{ik} H_{ik} BC_{ik} \quad (5a)$$

subject to:

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} H_{ik} \le T_{ik}, \forall\ i,k \quad (5b)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \ge I_i / 1000000, \forall\ i,k \quad (5c)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \le I_i / 300000, \forall\ i,k \quad (5d)$$

$$W_{ik} \ge I_i / 1000000, \forall\ i,k \quad (5e)$$

$$W_{ik} \le I_i / 300000, \forall\ i,k \quad (5f)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik} \le J_i, \forall\ i,k \quad (5g)$$

Interval linear programming (ILP) allows uncertainties to be directly communicated into the optimization process and resulting solutions, and it can reflect independent uncertainties in objective coefficients. Therefore, the model can be reformulated as follows:

$$Max\ f^{\pm} = \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm}(S_{ik}+A_{ik})P_{kh}M_{ikh} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm}(N_{ik}+A_{ik})P_{kh}(1-M_{ikh}) - \sum_{i=1}^{I}\sum_{k=1}^{K} L_k W_{ik}^{\pm} R_{ik} + \sum_{i=1}^{I}\sum_{k=1}^{K}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm} BC_{ik} \quad (6a)$$

subject to:

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{\pm} H_{ik}^{\pm} \le T_{ik}, \forall\ i,k \quad (6b)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{\pm} \ge I_i^{\pm} / 1000000, \forall\ i,k \quad (6c)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{\pm} \le I_i^{\pm} / 300000, \forall\ i,k \quad (6d)$$

$$W_{ik}^{\pm} \ge I_i^{\pm} / 1000000, \forall\ i,k \quad (6e)$$

$$W_{ik}^{\pm} \le I_i^{\pm} / 300000, \forall\ i,k \quad (6f)$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{\pm} \le J_i^{\pm}, \forall\ i,k \quad (6g)$$

Where $W_{ik}^{\pm}$, $H_{ik}^{\pm}$ and $I_i^{\pm}$ are interval parameters and variables; the superscripts '-' and '+' represent lower and upper bounds.

2.2. Method of Solution

According to Huang (1998), the submodel corresponding to the upper bound (f^{+}) should be firstly solved when the objective function is to maximize $f^{\pm}$ [13], and can be formulated as follows:

$$Max\ f^{+} = \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik}^{+} H_{ik}^{+}(S_{ik}+A_{ik})P_{kh}M_{ikh} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H}\alpha L_k W_{ik}^{+} H_{ik}^{+}(N_{ik}+A_{ik})P_{kh}(1-M_{ikh}) - \sum_{i=1}^{I}\sum_{k=1}^{K} L_k W_{ik}^{+} R_{ik} + \sum_{i=1}^{I}\sum_{k=1}^{K}\alpha L_k W_{ik}^{+} H_{ik}^{+} BC_{ik} \quad (7a)$$

subject to:

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{+} H_{ik}^{+} \le T_{ik}, \forall\ i,k \tag{7b}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{+} \ge I_i^{+} / 1000000, \forall\ i,k \tag{7c}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{+} \le I_i^{+} / 300000, \forall\ i,k \tag{7d}$$

$$W_{ik}^{+} \ge I_i^{+} / 1000000, \forall\ i,k \tag{7e}$$

$$W_{ik}^{+} \le I_i^{+} / 300000, \forall\ i,k \tag{7f}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{+} \le J_i^{+}, \forall\ i,k \tag{7g}$$

Correspondingly, the lower bound objective (f^-) can be presented as follows:

$$\begin{aligned} Max\ f^- = & \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H} \alpha L_k W_{ik}^{-} H_{ik}^{-} (S_{ik} + A_{ik}) P_{kh} M_{ikh} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{h=1}^{H} \alpha L_k W_{ik}^{-} H_{ik}^{-} (N_{ik} + A_{ik}) P_{kh} (1 - M_{ikh}) \\ & - \sum_{i=1}^{I}\sum_{k=1}^{K} L_k W_{ik}^{-} R_{ik} + \sum_{i=1}^{I}\sum_{k=1}^{K} \alpha L_k W_{ik}^{-} H_{ik}^{-} BC_{ik} \end{aligned} \tag{8a}$$

subject to:

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{-} H_{ik}^{-} \le T_{ik}, \forall\ i,k \tag{8b}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{-} \ge I_i^{-} / 1000000, \forall\ i,k \tag{8c}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{-} \le I_i^{-} / 300000, \forall\ i,k \tag{8d}$$

$$W_{ik}^{-} \ge I_i^{-} / 1000000, \forall\ i,k \tag{8e}$$

$$W_{ik}^{-} \le I_i^{-} / 300000, \forall\ i,k \tag{8f}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K} W_{ik}^{-} \le J_i^{-}, \forall\ i,k \tag{8g}$$

3. Case Study

Table I: Self-consumed electricity ratio under different probabilities

Level of electricity demand	Probability	Self-consumed electricity ratio		
		k=1	k=2	k=3
h = 1 (L = low)	0.2	[0.5,0.6]	[0.6,0.7]	[0.7,0.8]
h = 2 (M = medium)	0.6	[0.6,0.7]	[0.7,0.8]	[0.8,0.9]
h = 3 (H = high)	0.2	[0.7,0.8]	[0.8,0.9]	[0.9,1.0]

Table II: The electricity price under different period

Regions	The electricity price (RMB)		
	k=1	k=2	k=3
A	0.63	0.65	0.67
B	0.79	0.81	0.83
C	0.94	0.96	0.98

Consider a hypothetical case wherein a manager is in charge of planning distributed photovoltaic power capacity over 3 years (with three 1-year periods) in China. There are three regions which will be developed distributed photovoltaic power generation to satisfy electricity demand, including region A, region B, and region C. The three regions would be given 500 million financial subsidies from the government. Each region has different self-consumed electricity ratio in different periods. In this case, three levels are considered which are low, medium, and high [14], [15]. Each region accepts different level of light from sunshine every day. Therefore, the annual utilization length of solar power in three regions are different (i.e. [1489, 1661], [1460, 1591], [1270, 1391] hours). Carbon price would be 20 RMB/kg and power subsidies would be 0.42 RMB/kwh according to the national standards in the three regions. Pool purchase price in each region are 0.29, 0.35, 0.43 RMB/kwh respectively. Running cost of distributed photovoltaic power system in the three regions are [95000, 105000], [100000, 110000], [110000, 120000] RMB/ (MW Year) separately. The available rooftop area are [12, 15], [42, 45], [27, 30] km^2 in the three regions respectively. Table I shows the self-consumed electricity ratio and their associated probabilities. Table II shows the electricity price in the three regions in different periods.

The objective of the model is to maximize the system benefits through effectively allocating the financial subsidies in the three areas. Since there are multiple uncertainties and complexities existing in the system, the parameters and variables can be expressed as intervals and probability density distributions. Consequently, we have:

$$\begin{aligned} Max\ f^{\pm} = & \sum_{i=1}^{3}\sum_{k=1}^{3}\sum_{h=1}^{3}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm}(S_{ik}+A_{ik})P_{kh}M_{ikh} + \sum_{i=1}^{3}\sum_{k=1}^{3}\sum_{h=1}^{3}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm}(N_{ik}+A_{ik})P_{kh}(1-M_{ikh}) \\ & -\sum_{i=1}^{3}\sum_{k=1}^{3} L_k W_{ik}^{\pm} R_{ik} + \sum_{i=1}^{3}\sum_{k=1}^{3}\alpha L_k W_{ik}^{\pm} H_{ik}^{\pm} BC_{ik} \end{aligned} \tag{9a}$$

subject to:

$$\sum_{i=1}^{3}\sum_{k=1}^{3} W_{ik} H_{ik} \le T_{ik}, \forall\ i,k \tag{9b}$$

$$\sum_{i=1}^{3}\sum_{k=1}^{3} W_{ik}^{\pm} \ge I_i^{\pm} / 1000000, \forall\ i,k \tag{9c}$$

$$\sum_{i=1}^{3}\sum_{k=1}^{3} W_{ik}^{\pm} \le I_i^{\pm} / 300000, \forall\ i,k \tag{9d}$$

$$W_{ik}^{\pm} \ge I_i^{\pm} / 1000000, \forall\ i,k \tag{9e}$$

$$W_{ik}^{\pm} \le I_i^{\pm} / 300000, \forall\ i,k \tag{9f}$$

$$\sum_{i=1}^{3}\sum_{k=1}^{3} W_{ik}^{\pm} \le J_i, \forall\ i,k \tag{9g}$$

Where i = the type of region 1 for region A, 2 for region B, and 3 for region C; h = the level of self-consumed electricity ratio, 1 for low, 2 for medium, and 3 for high.

4. Result Analysis and Discussion

Fig. 2 and Fig. 3 present the upper and lower bounds of distributed photovoltaic power capacity respectively. The capacity of distributed photovoltaic power was allocated on the base of total financial subsidies, regional capacity constraint and regional rooftop area constraint. It is revealed that region B would have the most distributed photovoltaic power capacity during the planning periods. That is mainly because it would generate the highest benefits among the three regions. During period 3, each region will acquire the largest capacity of distributed photovoltaic power than period 1 and 2 as the periods passing by. In this way, system benefits will be optimized, and it will be [265, 359] millions.

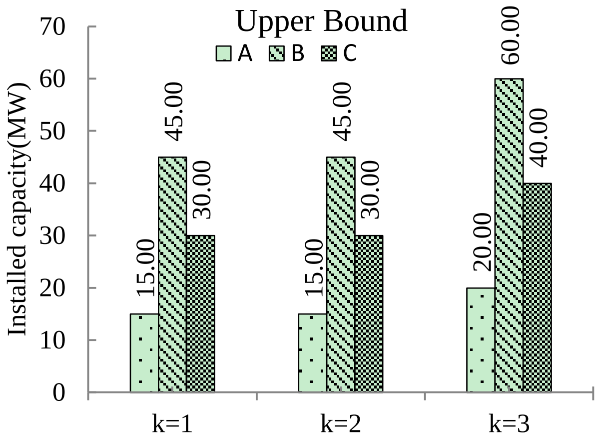

Fig. 2: Lower bound of distributed photovoltaic capacity

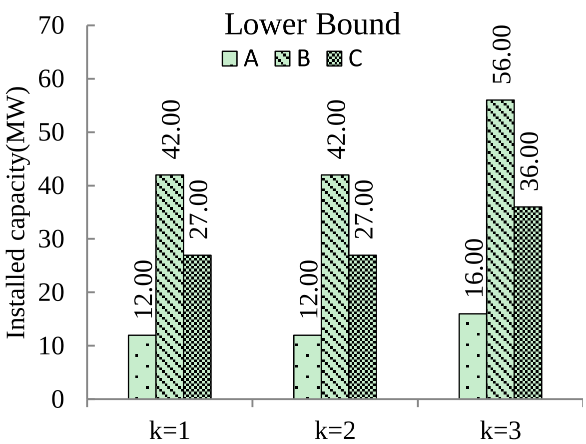

Fig. 3: Upper bound of distributed photovoltaic capacity

5. Conclusions

A stochastic interval linear programming method was formulated for facilitating identification of optimal distributed photovoltaic capacity development planning with limited subsidies under uncertainties. This method can deal with uncertainties expressed as both probability distributions and intervals. The proposed model was then applied to a hypothetical case of planning future capacity of distributed photovoltaic power generation planning in three regions of China where solar energy resources and proportion of electricity consumption were full of uncertainties. The formulated model could be transformed into two deterministic models, which corresponded to the lower and upper bounds of the desired objective. Solutions were obtained by solving the two submodels sequentially.

Results of this study could help:(a) facilitate reflections of multiple forms of uncertainties within a subsidies allocation system, (b) generate a number of cost-effective decision alternatives under different periods, allowing comprehensive analysis of trade-offs among system benefits and allocation schemes, and (c) demonstrate the availability of the model through applying to a case of distributed photovoltaic power planning management with the consideration of self-consumed electricity ratio. The results could be used for generating decision alternatives for helping decision-makers to identify optimal capacity allocation scheme under limited subsidies, available rooftop and grid access constraints.

6. Acknowledgements

This work was supported by the National Natural Science Foundation of China (Nos. 51522901 and 51421065), and the Fundamental Research Funds for the Central Universities (No. 2014KJJCB10).

7. References

[1] L.Q. Liu, C.X. Liu, Z.Y. Sun, et al. The development and application practice of neglected tidal energy in China. *Renew Sustain Energy. Rev.* 2011, 15 (2):1089-1097.

[2] L.M. Pekala, R.R. Tan, D.C.Y. Foo, et al. Optimal energy planning models with carbon footprint constraints. *Appl. Energy.* 2010, 86 (6): 1903-1910.

[3] Y. Zhu, Y.P. Li, G.H. Huang. Planning municipal-scale energy systems under functional interval uncertainties. *Renew. Energy.* 2012, 39 (1): 71-84.

[4] Y. Zhu, Y.P. Li, G.H. Huang. Planning carbon emission trading for Beijing's electric power systems under dual uncertainties. *Renew. Sustain. Energy. Rev.* 2013, 23: 113-128.

[5] Z. Kravanja, L. Cucek. Multi-objective optimization for generating sustainable solutions considering total effects on the environment. *Appl. Energy.* 2013, 101: 67-80.

[6] C. Unsihuay-Vila, J.W. Marangon-Lima, A.C. Z. De Souza, et al. Multistage expansion planning of generation and interconnections with sustainable energy development criteria: a multiobjective model. *Int. J. Elec. Power.* 2011, 33 (2): 258-270.

[7] M.Q. Suo, Y.P. Li, G.H. Huang. Multicriteria decision making under uncertainty: An advanced ordered weighted averaging operator for planning electric power systems. *Eng. Appl. Artif. Intel.* 2012, 25 (1): 72-81.

[8] P. Stigson, E. Dotzauer, J. Yan. Improving policy making through government - industry policy learning: The case of a novel Swedish policy framework. *Appl Energy*. 2009, 86(4): 399-406.

[9] China National Renewable Energy Centre (CNREC): http://www.cnrec.org.cn/

[10] Y.P. Cai, G.H. Huang, Q. Tan, et al. Planning of community-scale renewable energy management systems in a mixed stochastic and fuzzy environment. *Renew. Energy.* 2009, 34 (7): 1833-1847.

[11] L.M. Pekala, R.R. Tan, D.C.Y. Foo, et al. Optimal energy planning models with carbon footprint constraints. *Appl. Energy*. 2010, 86 (6) 1903-1910.

[12] National Energy Administration (NEA): http://www.nea.gov.cn/

[13] G. H. Huang. A hybrid inexact-stochastic water management model. *Eur. J. Oper. Res.* 1998, 107 (1): 137-158.

[14] M.A. Rosen. Energy considerations in design for environment: appropriate energy selection and energy efficiency. *Int J Green Energy.* 2004, 1 (1): 21-45.

[15] L.G. Swan, V.I. Ugursal, I. Beausoleil-Morrison. Hybrid residential end-use energy and greenhouse gas emissions model - development and verification for Canada. *Int J Green Energy*. 2013, 6 (1): 1-23.