Response to Reviewer#1

Reviewer#1: The article "A Demand Response Transaction Method for Integrated Energy Systems with Trigonometric Membership Function Based Uncertainty Model of Costumers' Responsive Behaviors s" proposed a demand response transaction model for integrated energy systems considering the uncertainty of customer demand response. The study is an interesting research topic, and it also has some practical significance. I'm in general satisfied with the paper. In the following, I describe some major and minor issues that need to be addressed by the authors:

Thanks to the reviewer for the comments and the valuable suggestions on the overall manuscript. Based on your comments, we have made corresponding amendments to the paper. Kindly find our responses to each of your comments and related modifications below.

Reviewer#1, Concern # 1: The overall presentation of the paper is weak. There are several bulk sentences throughout the paper which should be shortened. Please enhance the English level and grammar of the manuscript.

Author response:

Thanks to the reviewer for the comment. We checked the paper carefully and shorten all bulk sentences throughout the paper. Also, all grammatical errors have been revised. Long single sentences and complex sentence structures are revised and concise and the active voice has been used.

Details of the revision are available in **Author action.**

Author action:

All the authors proofread the manuscript to shorten the bulk sentences throughout the paper.

Reviewer#1, Concern # 2: The first section should include four parts: motivation, literature survey, contributions, and the organization of the manuscript. The main organization of the article should be presented in the introduction.

Author response:

Thanks to the reviewer for the comment.

The development of an integrated energy system (IES) should consider the safety, economy, and cleanliness. It integrates various energy resources such as natural gas and photovoltaic power in the region, and meets the multiple energy requirements of users. Thus the IES is becoming a hot spot for research in the energy field.

With the development of IES, the technological advances in demand response (DR) have become a key solution to achieve this energy transition. DR can effectively increase the active participation of consumers in the IES.

Incentive-based DR strategies are a very effective way of involving flexible loads in the grid DR process. Yet, for IESs that aggregate a large number of flexible loads, there exists uncertainty in the response volume they provide to the grid because of the specificity of the way it aggregates

resources.

In our paper, we propose a DR transaction model for the customers to actively interact with the IES. Considering that various types of flexible loads with different responsive potential and uncertainty in the customers may influence the transaction results, we apply the fuzzy theory with trigonometric membership-function to describe the uncertainty of these flexible loads.

In response to your valuable advice, we added the main organization in the end of the introduction.

Details of the revision are available in **Author action.**

Author action:

The contributions of this paper are threefold：

1) We introduce the analysis of demand respond uncertainty. Additionally, the DR load uncertainty models of curtailable load, translated load and replaceable load are proposed respectively.

2) A DR transaction model is investigated. In this model, various types of flexible load response volume uncertainty are taken into consideration.

3) We point out the relationship between the uncertainty level of user response and the incentive level and utilize the trigonometric membership fuzzy function to construct the uncertainty model of flexible load response. Therefore, the transaction model containing fuzzy variables is transformed into a deterministic model for a solution.

The remainder of this paper is arranged as follow. Section Ⅰ introduces the DR load uncertainty analysis and modeling. In Section Ⅱ, a DR transaction model that considers uncertainty of flexible loads is given. Section Ⅲ elaborates on the process of the model uncertainty. Case study is given in Section Ⅳ to evaluate the impact of the uncertainty of user response volume and the fuzzy chance constraints confidence level on the transaction results of transaction stake-holders. Conclusions are presented in Section Ⅴ.

Reviewer#1, Concern # 3: The conclusion can be revised. This reviewer suggests improving the flow of the conclusion section. Start with a brief explanation of the paper goal (like the abstract), but make sure that the conclusion should be different from the abstract. Provide the main findings/ claims. Then finalize your conclusion by providing one or two suggestions for future work.

Author response:

Thanks to the reviewer for the comment.

In this paper, the impact of uncertainty in flexible load response on DR transactions is considered. First, the uncertainty problem of incentive-based DR is analyzed, and the relationship between the level of incentive and the range of fluctuations in the user response volume is investigated. Subsequently, the treatment of uncertainty is introduced, and this paper uses fuzzy variables to represent the user response volume. Based on this, a trigonometric membership function is used to represent the uncertainty level of user response quantity for different types of flexible loads. Finally, for the objective function and chance constraints containing fuzzy variables, they are converted into explicit equivalence classes and then solved. The case study section examines the impact of the

uncertainty of user response volume on the revenue of each transaction entity and the impact of the fuzzy chance constraints confidence level on the response revenue. The results demonstrate that the revenue of each transaction entity decreases to a certain extent when the uncertainty of user response volume is considered, and the social welfare of the whole transaction increases as the confidence level of the chance constraint changes from high to low.

We revised the conclusion carefully. Both the main findings and future work were added to the conclusion.

Details of the revision are available in **Author action.**

Author action:

In this paper, the impact of uncertainty in flexible loads response on DR transaction is considered. First, the uncertainty problem of incentive-based DR is analyzed, and the relationship between the level of incentive and the range of fluctuations in the user response volume is investigated. Subsequently, the treatment of uncertainty is introduced, and this paper uses fuzzy variables to represent the user response volume. Based on this, a trigonometric membership function is used to represent the uncertainty level of user response quantity for different types of flexible loads. Finally, for the objective function and chance constraints containing fuzzy variables, they are converted into an explicit equivalence classes and then solved. The case study section examines the impact of the uncertainty of user response volume on the revenue of each transaction entity and the impact of the fuzzy chance constraints confidence level on the response revenue. The results demonstrate that the revenue of each transaction entity decreases to a certain extent when the uncertainty of user response volume is considered, and the social welfare of the whole transaction increases as the confidence level of the chance constraint changes from high to low.

The proposed method of dealing with user response uncertainty in this paper provides some ideas and suggestions to solve the problems faced by flexible loads when participating in DR, but it can still be extended in the following two aspects. Firstly, the study of flexible loads response strategy under multiple time scales. The research conducted in this paper does not consider the time scale, and does not study the regulation of flexible loads in multiple time scales such as day-ahead, intra-day and real-time. In fact, in the case of approaching time scale, the types of flexible users that can participate in grid DR will be reduced continuously, and the uncertainty of user response will also be reduced continuously, even in the real-time stage is possible without considering the problem of user response uncertainty. Secondly, the study of user uncertainty under multiple response mechanisms. In this paper, we only consider the problem of response uncertainty of flexible loads under contract constraints, but in fact, some flexible loads can also participate in the DR of the grid under tariff guidance, and their response uncertainty cannot be ignored.

Reviewer#1, Concern # 4: Some mistakes in the template of references should be corrected. Please consider the template of the journal significantly and modify the form and title of the table according to the template.

Author response:

First of all, we appreciate your comments. By comparing the template, we found that there are

definitely some mistakes in the format, including references and title. Your suggestions were extremely helpful to us. We then systematically corrected the formatting errors that appeared in the paper according to the template. The form and title of the table were also modified according to the template.

Details of the revision are available in **Author action.**

Author action:

All the authors proofread the manuscript to correct the mistake in the template of references carefully.

Reviewer#1, Concern # 5: The abstract requires revisions to reflect the key ideas of this paper as well as the details of the proposed approach. The main contributions of the paper are not clearly expressed. The authors should give a detailed statement to highlight the novelty in section I

Author response:

Thanks to the reviewer for the comment.

In this paper, the impact of uncertainty in flexible load response on DR transactions is considered. First, the uncertainty problem of incentive-based DR is analyzed, and the relationship between the level of incentive and the range of fluctuations in the user response volume is investigated. Subsequently, the treatment of uncertainty is introduced, and this paper uses fuzzy variables to represent the user response volume. Based on this, a trigonometric membership function is used to represent the uncertainty level of user response quantity for different types of flexible loads. Finally, for the objective function and chance constraints containing fuzzy variables, they are converted into explicit equivalence classes and then solved. The case study section examines the impact of the uncertainty of user response volume on the revenue of each transaction entity and the impact of the fuzzy chance constraints confidence level on the response revenue. The results demonstrate that the revenue of each transaction entity decreases to a certain extent when the uncertainty of user response volume is considered, and the social welfare of the whole transaction increases as the confidence level of the chance constraint changes from high to low.

To reflect the key ideas of this paper as well as the details of the proposed approach. We revised the abstract according to you comment. Also, the main contributions of the paper were clearly expressed and the novelty was given in section I.

Details of the revision are available in **Author action.**

Author action:

Abstract revision:

As an important regulation tool for power systems, demand response can greatly improve system

flexibility and economy. However, when an integrated energy system with a large number of flexible loads is aggregated for DR transaction, the uncertainty in the amount of load response should be taken into account. Therefore, a DR transaction model for an integrated energy system that considers the uncertainty of customer DR is proposed in this paper. At first, the uncertainty of incentive-based DR is analyzed, and the relationship between the incentive level and the fluctuation of customer response volume is investigated. The flexible loads are classified into curtailable loads, translatable loads, and replaceable loads. Secondly, fuzzy variables are used to represent the response volume of users. After that, a trigonometric membership function is used to represent the degree of uncertainty in the response volume of different flexible loads. Finally, the objective functions and chance constraints containing fuzzy variables are converted into explicit equivalence classes for solving. In the case study, the impact of the uncertainty of user response volume on the revenue of each transaction entity and the impact of the fuzzy chance constraint confidence level on the response revenue are investigated. The results show that the revenue of each transaction entity decreases to a certain extent under the consideration of the uncertainty of user response volume; the social welfare of the whole transaction increases as the confidence level of the chance constraint changes from high to low

Revision in section I

Traditional methods usually transform a certain optimization model into a stochastic optimization via adding random variables with a bounded interval or a certain probability distribution [1], [2]. These methods are required to form the accurate probability distribution of every random variable, while there are numerous flexible loads participating in the DR and it is unfeasible to confirm their accurate probability. Thus, a robust-based optimization model is proposed to tackle this problem [3], yet the results solved by this model could be quite conservative along with the poor economy of the system. Considering both the characteristics of flexible loads and the economy of the system, we eventually utilize the fuzzy theory with trigonometric membership-function. Trigonometric membership-functions of uncertain parameters can be obtained by an expert system when a fuzzy number lacks historical information, so this method is of low dependence on historical data and a good description of the uncertainty.

Based on the above problems, this paper focuses on the uncertainty of the excitation-type flexible load response and proposed a DR transaction model for the customers to actively interact with the IES. Firstly, the uncertainty problem of the incentive-based DR method is studied. The relationship between the uncertainty level of user response and the incentive level has been pointed out. Secondly, fuzzy variables are used to represent user response; then, the trigonometric membership fuzzy function is used to construct the uncertainty model of flexible load response. Finally, the transaction model containing fuzzy variables is transformed into a deterministic model for a solution.

The contributions of this paper are threefold：

1) We introduce the analysis of DR uncertainty. Additionally, the DR load uncertainty models of curtailable load, translated load, and replaceable load are proposed respectively.

2) A DR transaction model is investigated. In this model, various types of flexible load response volume uncertainty are taken into consideration.

3) We point out the relationship between the uncertainty level of user response and the incentive

level and utilize the trigonometric membership fuzzy function to construct the uncertainty model of flexible load response. Therefore, the transaction model containing fuzzy variables is transformed into a deterministic model for a solution.

The remainder of this paper is arranged as follows. Section Ⅰ introduces the DR load uncertainty analysis and modeling. In Section Ⅱ, a DR transaction model that considers the uncertainty of flexible loads is given. Section Ⅲ elaborates on the process of the model uncertainty. The case study is given in Section Ⅳ to evaluate the impact of the uncertainty of user response volume and the fuzzy chance constraints confidence level on the transaction results of transaction stakeholders. Conclusions are presented in Section Ⅴ.