Simulation-based policy making for autonomous decentralized energy systems -rice husk use in Thailand-

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Abstract:
This paper introduces the simulation-based policy-making methodology for autonomous decentralized decision-making systems and shows its effectiveness by taking renewable energy (rice husk) use in Thailand as an example. The stakeholders, e.g., energy consumers, energy suppliers, retailers and national/local governments included in the renewable energy systems, are considered to be the autonomous decentralized decision-makers. However, the criteria and constraints of the stakeholders' decision-making are usually unknown to policy makers/planners, and even the level of autonomy, that is, the capacity of decision-makers, may be included in the design targets of education and policy. This study has developed the simulation model for designing the autonomous decision-making systems including the stakeholders of the market with a variety of transaction rules. First, the simulation-based policy-making approach is introduced. Second, the decision-rules of the stakeholders in the market of rice husk in Thailand were collected and analyzed based on the results of the interviews and the questionnaire survey for developing the behavioral model. And finally, several simple sets of policy rules for the energy market are examined by using the simulation model for demonstrating the effectiveness of the simulation-based policy-making approach.

Keywords: *Simulation-based design; Autonomous decision making; Decentralized energy system; Renewable energy*

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1. Introduction

Renewable energy resource will be unquestionably indispensable and will be required earlier in the countries where the conventional energy resource supply is not sufficient. The renewable energy systems usually distribute with lower energy density, and, therefore, the plants are inevitably small-scale and decentralized. And the renewable energy systems largely depend on their local conditions such as geography, climate, population and local stakeholders who are the participants of the energy market such as energy consumers, energy suppliers, retailers and national/local governments. One of the important properties of the decentralized stakeholders is "autonomy" in decision making. Autonomous decision making about energy means that the decision-makers decide the energy related behavior themselves. It should be noted that the autonomous energy system is different from the independent energy system which can supply the energy required itself. Autonomous decision-makers can depend on the energy supply of others if necessary. The problem of decentralized decisions is that its information such as criteria, constraints, societal environment, supply and demand properties, is only partly known to policy makers/planners. Even the level of autonomy, that is, the capacity of decision-makers, can be improved by redesigning the education and the related policies. Therefore, the policy makers should design the policy only based on the uncertain information about the decision making of the diversified stakeholders. This paper introduces the simulation-based policy making approach for autonomous decentralized energy systems. And the effectiveness of the simulation-based policy making approach is demonstrated by examining the energy market rules with the simulation model. The model of stakeholders' behavior was developed based on the results of the interviews and questionnaire survey in Thailand.

2. Microscopic and Macroscopic Viewpoints for Energy Systems Design

As is shown in Fig. 1 the decision-makings related to renewable-energy use in a region usually form a hierarchical nested structure. The decision-making of one layer has interaction with the decisions

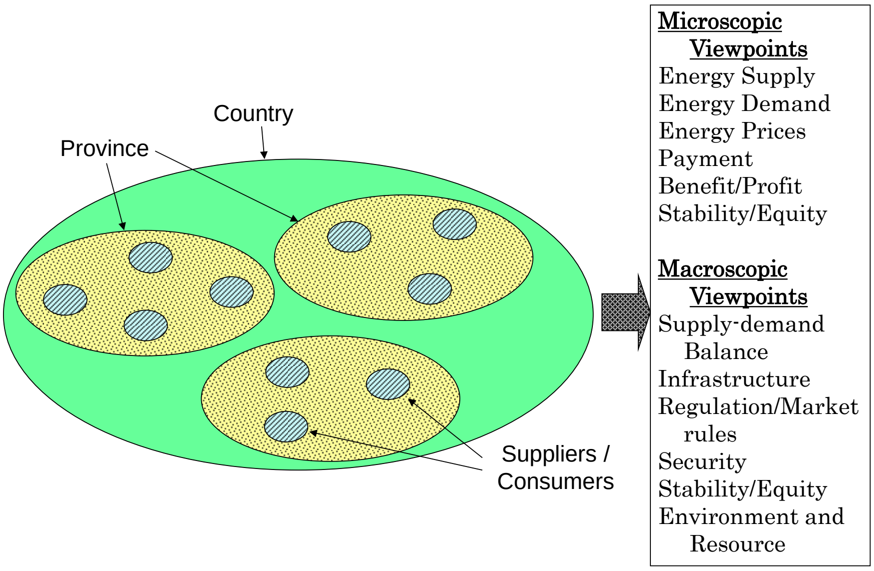

Fig. 1 Hierarchical nested structure of "Autonomous Decentralized Energy Systems" and macroscopic and microscopic viewpoints.

of different layers, and the rules for decision-making should be decided by considering the nested structure. In this paper we will focus on the microscopic (of the lowest level) and macroscopic (of the highest level) decision making for simplicity. The behavior of each decision-maker depends on its viewpoint such as criteria and constraints of decision making. However, needless to say, the total-system design should depend on the total-system (macroscopic) viewpoints such as stability of the market behavior as well as the microscopic viewpoints. What is important in system design is to take both of the macroscopic and the microscopic viewpoints into account.

3. Simulation-based Design Framework

The framework for designing Autonomous decentralized decision-making systems is briefly shown in Fig. 2 (Cai and Tezuka, 2008). It is based on the idea of the "worst-case simulation", whose design concept is that the policy should be designed so that the expected worst case of the system behavior might be acceptable to the policy makers and the stakeholders. Therefore, the simulation-

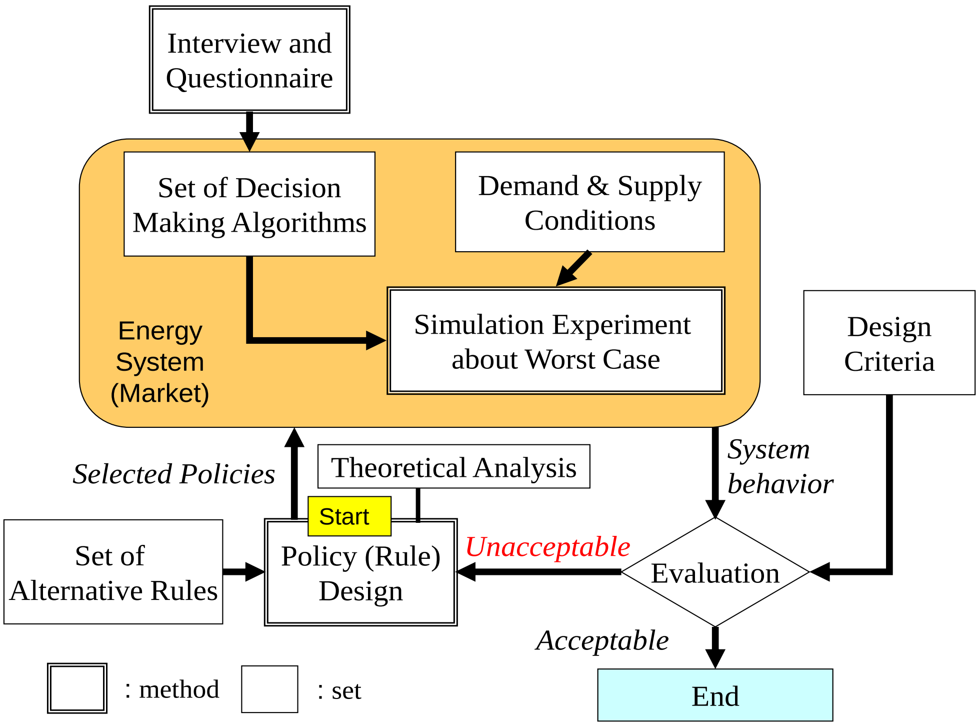

Fig. 2 Simulation-based system design framework (Cai, Tezuka, 2008).

based experiment is conducted so as to examine whether or not the expected worst case would be acceptable from macroscopic and microscopic viewpoints.

4. Survey of Rice Husk Use in Thailand

The rice husk price fluctuates so largely in Thailand and is around 1500 Baht/ton in Suphanburi Province. This price is high when compared to other fuels. However, the price is around 500 Baht/ton in Chiangrai Province (Energy for Environment Foundation, 2014). It is considered that some policies for promoting rice husk use are the reason for the price variation and fluctuation. This study aims to find appropriate policies for stabilizing the rice husk price. We did the interviews and the questionnaire survey on the rice husk use and trade near Bangkok, Thailand. The results are used for developing the behavioral model of stakeholders.

Figure 3 shows the amount of unused rice husk in Thailand. Most of the unused rice husk is that of small-scale rice mill plants. The difficulty in rice husk collection is one of the reasons of unused rice husk. However, the distance of rice husk transportation is sometimes more than 100 km, which means that the rice husk utilization can be more efficient by disseminating information to the suppliers and the consumers of the rice husk under appropriate rules of the market.

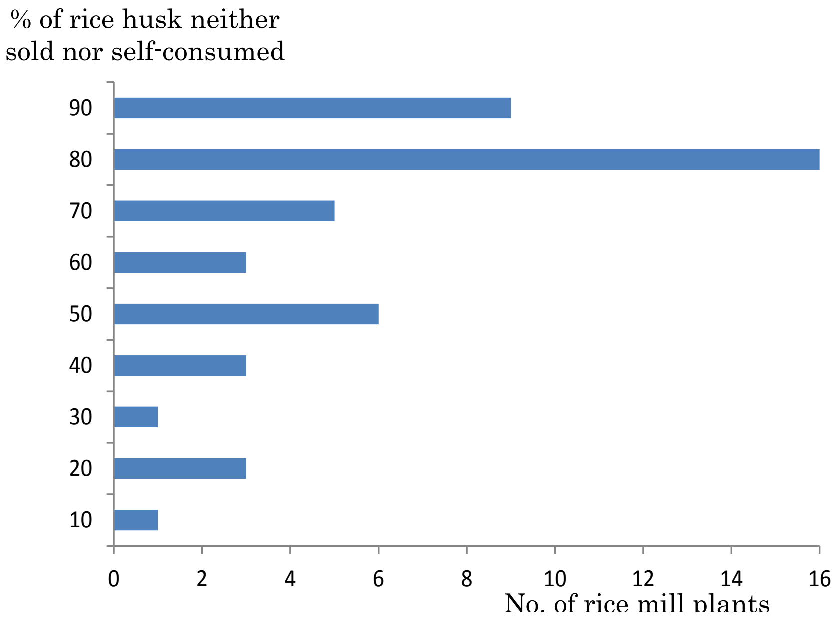

Fig. 3 Current situation of rice husk use (% of the unused).

The purposes of rice husk use are diversified, e.g., fuel for brick making, feeding livestock, material for charcoal, paper, brick, fertilizer in addition to the fuel for power generation. Current trading of rice husk is often due to non-economic conditions such as longtime relationship with other stakeholders. The price of rice husk is also decided arbitrarily by the stakeholders. It is also because there is no established market for rice husk trading and it may be the reason for the higher price of rice husk. This study evaluates the relationship between the policy and the rice husk price.

5. Simulation Analysis of Rice-husk Use by Stakeholders

In this study Suphanburi Province in Thailand is selected as a study area. The rice mill plants in a sub-district are aggregated into one plant located at the center of the sub-district in the simulation. The numbers of rice mill plants and rice-husk power plants are resultantly 80 and 10, respectively. The rice husk use depends on the longtime convention observed in the current trade of rice husk. Therefore, the amounts of rice husk to be traded are assumed to be given by rice-mill owners in the simulation model. And the rice-husk prices for each of the power plants are generated by using random numbers since there is no mechanism for deciding the rice husk price in the current rice-husk market. This means that the power plant has one rice-husk price which is different from the prices with which the other power plants purchase the rice husk. And each of the rice-husk based power plants decides the rice mill plants, from which the power plant purchases the rice husk, and the amount of husk to be purchased by minimizing the cost for its power generation. After the selection by power plants the rice mill owners decide the power plants to which rice husk is sold (Trade 1). In the second trade simulation (Trade 2) the power plant which still needs some amount of rice husk for power generation raises the rice-husk price to get more rice husk, and then the same market-simulation procedures are conducted until no additional rice husk is traded in the simulation.

Six scenarios of market rules are prepared for simulation. The capacity of the rice mill plant is more than 100ton-rice/day for Scenario S1-5 due to the reasons explained in Section 4.
S1. Business-as-usual Scenario with current rules of rice husk trading,
S2. Scenario where alternative fuel is allowed to be used by power plants,
S3. Scenario where the power generation output of each power plant is allowed to increase,
S4. Scenario where the government purchases all rice husk and sell it with the price, 650 Baht/ton,
S5. Scenario where the rice husk is sold to the power plants designated beforehand so that the transportation cost might be minimized,
S6. Scenario where rice husk from small-scale rice mill plants are delivered with the price of 750 Baht per ton and the policies of S5 and 6 are also implemented.

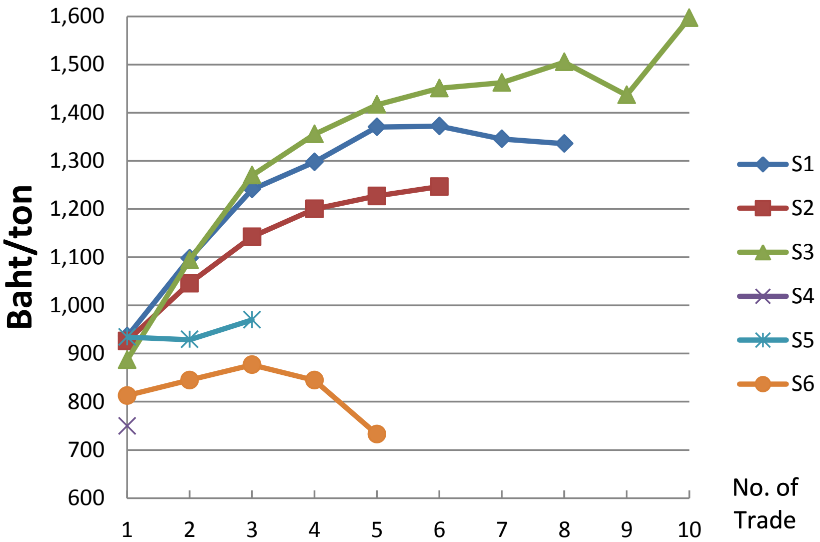

Fig. 4 Comparison of six scenarios as for price fluctuation.

The simulation results about the rice-husk price are shown in Fig. 4. The policy mix scenario (S6) shows better performance as for the price fluctuation.

The simulation-based design methodology proposed can include a variety of autonomous decision behavior which cannot be easily included in normative-model approach. This fact means that this approach can be applied to more practical policy-making situations.

Autonomous property of the stakeholders is indispensable in considering the rice-husk use with a variety of manners. Stakeholders' capacity for autonomy should be improved through training and education for realizing more stable and robust decentralized energy systems.

6. Conclusion

Performance of the simulation-based policy design approach is demonstrated in this paper. As a further study practical stakeholders including policy makers are required to join the simulation.

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