

## ALTERNATIVE STRUCTURES OF DISTRIBUTION SECTOR FOR NEUTRAL DISTRIBUTION SYSTEM OPERATION IN KOREA

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### ABSTRACT

*As some of existing distribution company (DISCO) struggles to perform the function of the future distribution business, discussion from a structural point of view is also necessary. The structure of DISCO affects the characteristics including its incentive to invest in network, neutrality in operation and connection of third-party generators, etc. Thus, it is necessary to evaluate the characteristics of each structure of DISCO. There have been studies evaluating electric utility structures. However, since future distribution business is not considered in the previous studies, this study presents six evaluation indexes to compare the structures of DISCO. Four structures of DISCO (vertically integrated utility, legally unbundled, ownership unbundled, independent distribution system operator) are evaluated based on the proposed indexes. It is found that each structure has pros and cons in terms of each index. The analysis in this study can help a policy maker to select a reasonable structure of DISCOs that meets policy objectives.*

### INTRODUCTION

Due to the concerns on climate change, low-carbon energy sources including distributed renewable energy sources have been increasing around the world [1]. Following the global trend, the public interest in low-carbon energy also arises in Korea. However, the Korea is far behind other OECD countries in terms of share of renewable energy in final energy consumption. One of the reasons of the small share is the current fit-and-forget connection scheme. The fit-and-forget scheme guarantees maximum output of distributed energy resources (DERs) without any control signal. If any condition is violated, the fit-and-forget scheme requires grid reinforcement or extension for increasing hosting capacity for DER, which leads to not only the delay of connections but also excessive investment cost.

Active network management (ANM) enables a utility to monitor the state of buses, calculate the optimal power flows, and deliver control signal to DERs [2]. Distribution system operator (DSO) using ANM, which is also called ‘active DSO’, does not need to stick to the fit-and-forget scheme. Instead, a DSO can utilize the resources and facilities in the distribution network, which enables rapid increase of DERs penetration. The function of ANM includes dispatch of DERs. Thus, high level of neutrality is required to active DSO.

The structure of power industry affects the main role of

distribution companies (DISCOs) such as DER connection and distribution system operation. Currently, the DISCO in Korea is struggling to perfectly perform the function of the future distribution business, so discussion from a structural point of view is also necessary. Thus, this study examines and compares a few alternative structures of DISCO to evaluate the characteristics of alternative structures.

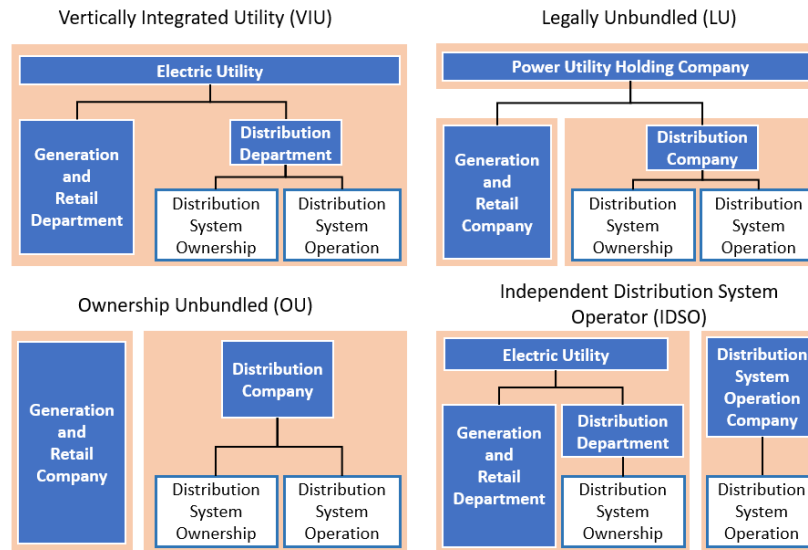
There were studies focused on pros and cons of the structures of operation and ownership of power industry. However, one only focused on transmission system [3], another didn't consider active operation of distribution system [4], and the other only focused on a few detailed indicators [5]. Therefore, in this study, six indexes are proposed to evaluate the alternative structures of DISCO in the view of the ownership and operational authority models. Then, the evaluation results based on the proposed indexes and the associated discussion are presented.

The rest of this paper is organized as follows: Section 2 describes the structures of DISCO; Section 3 describes the proposed evaluation indexes; Section 4 shows the evaluation results; Discussions are given in the final section.

### STRUCTURE OF OWNERSHIP AND OPERATIONAL AUTHORITY IN DISTRIBUTION SECTOR

This section describes four structures of DISCO with different ownership and operational authority. There are common assumptions applied to all the structures. Firstly, transmission sector is not assumed in meticulous. In addition, the power generation department/company is assumed to own DER. It is also assumed that power sector and the retail sector are in competitive market with multiple entities.

There are two entities around the distribution business. One is distribution system operator and the other is distribution network owner [4]. The distribution system operator has authorities for controlling distribution assets and facilities, and dispatching third-party DERs in its network under certain contract. Also, the operator establishes a long-term distribution network planning. On the other hand, the distribution network owner manages the network facility. In addition, the owner invests to the network planning established by the operator. It is possible for the two entities to be integrated entity or separated entities. Besides, there are multiple structures depending on whether the distribution business is consolidated with the competitive business (generation, retail) [4].



**Figure 1** Structure of ownership and operational authority for each unbundling case

Figure 1 shows four structures with different operational authority and distribution network ownership. In the figure, each orange box represents single company, thus the separate orange box means separate companies. The business sector is represented in blue boxes. White colored boxes with blue edges represent functions related to the distribution business.

### Vertically Integrated Utility

The vertically integrated utility (VIU) structure on the upper left is a traditional utility structure that manages all supply chain including generation, (transmission), distribution, and retail. Under the VIU structure, transfer of funds and personnel is unrestricted among the departments. However, it is also possible to segregate the account of each department. Because of the characteristics of finance and personnel, it tends to reflect the interests of entire company in making investment decision. Therefore, the independence of the distribution business from the competitive business (generation and retail) is relatively low compared to other structures.

### Legally Unbundled

Legally unbundled (LU) is a structure that the competitive business (generation, retail) and the DISCO are legally unbundled. But they still belong to a holding company as subsidiaries. Depending on the laws and regulations in the countries, there are various degrees of acceptability regarding transfer of funds between subsidiaries. However, LU structure tends to be more restrictive than the VIU model. However, LU DISCO is not completely independent from the holding company because transfer of personnel between subsidiaries is still acceptable. Nevertheless, not holding company but LU DISCO owns and operate the distribution system.

### Ownership Unbundled

Ownership unbundled (OU) is a structure that OU DISCO is separated from competitive business (generation, retail) company. Under this structure, the OU DISCO has both ownership and control over the distribution system. Since OU DISCO has higher business independence than VIU or LU DISCO, there is a more favorable aspect to implement fair industrial structure.

### Independent Distribution System Operator

The independent distribution system operator (IDSO) does not have ownership of the distribution network but only operates the resources. Under the IDSO structure, the VIU company also coexist with IDSO. The VIU company owns both the distribution network and DER but receive dispatch signal from IDSO. The fairness in operation of the DERs is ensured by separating the entity that owns the DER and the DSO who dispatches.

## **INDEXES EVALUATING STRUCTURES OF DISTRIBUTION BUSINESS**

The four DISCO structures have different degree of independence of the that lead to different characteristics and pros and cons. To evaluate the pros and cons of each structure, the proposed indexes are as follows which are based on [4] and [6]:

1. Incentives to invest in distribution network;
2. Efficiency of incentive regulation;
3. Fairness in connecting 3rd party DER;
4. Fairness in distribution system operation;
5. Transitional costs;
6. Economy of scope between distribution and retail sectors.

It is hard to integrate each of the index into summed index because they represent different characteristics. Therefore, we evaluated each structure with six indexes with a score between 0 and 1, respectively.

### **Incentives to Invest in Distribution Network**

In the case the competitive business and distribution business are integrated, it tends to actively invest in the distribution network to increase profit in competitive business. However, if the distribution business is independent from competitive business, the incentive as means to increase the profit of competitive business does not exist. Instead, the investment can be induced through additional incentive regulations. The incentive regulation is used by regulation authority to induce the DISCO to the intended direction such as fast connection of DERs. Unlike the previous cases where ownership and operating rights are combined, the two can be separated. In the United States, where ownership on network and operating rights are separated in some market, the concern exists that there is little incentive to construct new transmission [6]. Thus, the separation of ownership and operational authority is assessed to have an ineffective effect on investment in the distribution [7].

### **Efficiency of Incentive Regulation**

Incentive regulation is a regulatory method used to derive the business of a utility company in a certain direction by providing award or penalty. The award or penalty are decided based on performance of the utility compared to government policy objectives. Incentive regulations applied to network businesses assesses such as cost, reliability, etc. The structure of DISCO affects the efficiency of incentive regulation. If DISCO is combined with competitive business, the DISCO tends to conduct business that meets the interests of the entire company, not the profit of the distribution business alone. In this case, the incentive regulation is one of the factors affecting the profit of the whole company, so the effectiveness of incentive regulation is low. However, if the DISCO is independent from competitive business, the influence of the incentive regulation on the DISCO is large. In addition, there is a possibility of transferring costs to the distribution business if it is possible to transfer costs internally within integrated company. The cost transferability decreases transparency of distribution costs and reduces the efficiency of incentive regulation. In addition, the greater the independence of the distribution business, the greater the transparency of network management and investment costs. As a result, the higher the independence of the distribution business, the higher the efficiency of the incentive regulation.

### **Fairness in Connecting Third Party DER**

The increase in the third party DER, which is not owned by the generation and retail company, decreases the profit of the generation and retail company. For the case of power generation companies, the amount of electricity that the company sell reduces.

In the case of a retail company, when a DER is installed

by a consumer, the profit of the retail company is also reduced. Therefore, there is an incentive to discriminate against the connection of third party DERs if the distribution company shares interests with the development / retail company.

Discrimination on connection and management of third party DER consist of non-pricing discrimination and price discrimination. Non-price discrimination includes delays in repair, delays in connection, and incomplete information delivery. One example of price discrimination is shifting of transmission reinforcement cost to distribution reinforcement cost.

### **Fairness in Distribution System Operation**

Distribution system operator (DSO) is responsible for real-time distribution system operation without violating network constraints. The DERs should follow the output direction from the DSO. For example, if a violation of the system constraint is expected due to excessive output from the DER, the curtailment decision is instructed to the DER. If a DSO having operational authority owns a DER, controversy over fairness in operation may arise. When the DSO instruct the curtailment, there is an incentive to direct more curtailment to the third party owned DERs as compared to instructed curtailment to DSO owned DER. For each DISCO structure, it is assumed that DER is owned by the following entities. Under the VIU structure, DER is owned by the VIU generation department. Under the LU structure, DER is owned by the generation subsidiary. Under the OU structure, DER is owned by the generation company. Lastly, under the IDSO structure, DER is owned by generation department of the VIU.

### **Transitional Costs**

As transition from one structure to the other structure occurs, transitional costs are incurred. Two transitions can be considered, respectively: transfer of operational authority and transfer of ownership. When transferring operational authority, cost of introduction and management of ICT solution, personnel adjustment costs, and office acquisition costs, etc. arise. Costs relating with the ownership transition may include legal costs associated with transferring ownership and re-contracting costs for contracts with third parties. It is assumed that the cost of transferring ownership is greater than the cost of transferring the operational authority.

### **Economy of Scope between Distribution and Retail Sectors**

If the distribution business and the retail business are tied to the same company, then an economy of scope can occur. For example, economies of scope may exist in areas such as call centres and billing systems. Also, in the case of marketing, the cost of advertising by group companies is relatively low.

**Table 1** Result of evaluation of structures of distribution business

Indexes Detailed items [Maximum scores]	VIU	LU	OU	IDSO	
				VIU w/ DER	VIU w/o DER
<b>Incentives to invest in distribution network</b>	<b>1</b>	<b>0.8</b>	<b>0.6</b>	<b>0.8</b>	<b>0.4</b>
Consolidation between distribution and retail [0.4]	0.4	0.2	0	0.4	0
Consolidation between distribution and DER [0.4]	0.4	0.2	0	0.4	0.4
Integration between ownership and operational authority [0.2]	0.2	0.2	0.2	0	0
Incentive through incentive regulation [0.4]	0	0.2	0.4	0	0
<b>Efficiency of incentive regulation</b>	<b>0.5</b>	<b>0.8</b>	<b>1</b>	<b>0.5</b>	<b>0.5</b>
Cost transparency [0.5]	0	0.3	0.5	0	0
Preventing cost escalation through additional regulation [0.5]	0.5	0.5	0.5	0.5	0.5
<b>Fairness in connecting third party DER</b>	<b>0</b>	<b>0.5</b>	<b>1</b>	<b>0</b>	<b>0.5</b>
Separation between distribution and retail [0.5]	0	0.25	0.5	0	0.5
Separation between distribution and DER [0.5]	0	0.25	0.5	0	0
<b>Fairness in distribution system operation</b>	<b>0</b>	<b>0.5</b>	<b>1</b>	<b>1</b>	<b>1</b>
Separation between distribution system owner and distribution operator [1]	0	0.5	1	1	1
<b>Transitional costs</b>	<b>1</b>	<b>0.5</b>	<b>0</b>	<b>0.7</b>	<b>0.7</b>
Transfer of ownership of distribution system [0.7]	0.7	0.35	0	0.7	0.7
Transfer of operational authority in distribution system [0.3]	0.3	0.15	0	0	0
<b>Economy of scope between distribution &amp; retail sectors</b>	<b>1</b>	<b>0.8</b>	<b>0</b>	<b>1</b>	<b>1</b>
Consolidation between distribution and retail [1]	1	0.8	0	1	1

## RESULT

Based on the proposed index, the structures are evaluated using detailed evaluation indexes. Table 1 shows the evaluation results. In the first column, the items with grey background are the proposed indexes. Detailed items in each index and assigned maximum scores are shown under each index. The second to last columns are scores of the index (grey background) and scores the detailed items (white background) of each structure.

The VIU model showed high scores in the *incentives to invest in distribution network*, *transitional costs*, and *economy of scope between distribution and retail*. But, showed low scores in *efficiency of incentive regulation*, *fairness in connecting third party DER*, and *fairness in distribution system operation*. The VIU structure received high scores in terms of investment and cost due to its integrated structure. However, it received a low score in fairness due to the non-transparency of the company from outside of view and the inequity of competition between entities other than VIU and VIU.

LU structure get high scores on *incentives to invest in distribution network*, *efficiency of incentive regulation*, and *economy of scope between distribution and retail sectors*. But LU is estimated low in *fairness in connecting third party DER*, *fairness in distribution system operation*,

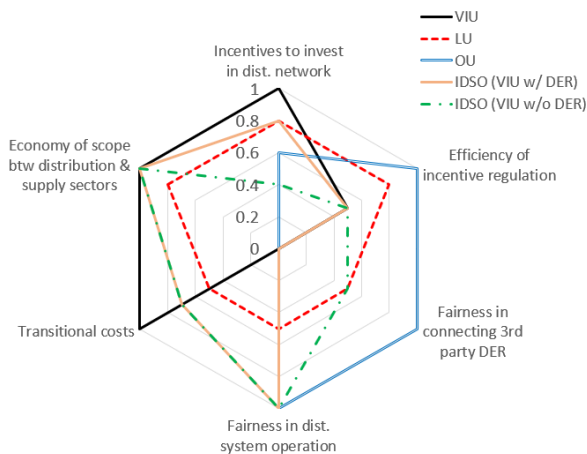
and *transitional costs*. Compared to the VIU scores, the investment or cost aspects are rated as little negative, while the fair scores are rated higher.

The OU model showed high scores on *efficiency of incentive regulation*, *fairness in connecting third party DER*, and *fairness in distribution system operation*. But showed a medium score in *incentives to invest in distribution network* and a lower score in the *transitional costs* and *economy of scope between distribution and retail sectors*. OU received a high score in fairness due to the high independence of the distribution business, but received a low score in the investment and economy indexes.

In the IDSO model with VIU having DERs, the structure shows a high score in *incentives to invest in distribution network*, *fairness in distribution system operation*, *transitional costs*, and *economy of scope between distribution and retail sectors*. But it has medium scores in *efficiency of incentive regulation* and low scores in *fairness in connecting 3rd party DER*. Compared with VIU model, investment incentives and transfer costs are lower, but operating fairness is much higher. This is the result of devolving the operational rights to IDSO, which has no common interest with any DERs.

The IDSO model with VIU without DERs has high scores in the *fairness in the operation*, *transitional costs*, and the *economy of scope*. On the other hand, it is valued a

medium score in *incentives to invest in distribution network*, *efficiency of incentive regulation* and *fairness in connecting 3rd party DER*. Compared to result of IDSO with VIU having DERs, it received a higher score in the *fairness in connecting 3rd party DER*, while it gets lower score in *incentives to invest in distribution network*. The scores of all structures are summarized in hexagonal graph in Figure 2 .



**Figure 2** Costs and Benefits Assessment Results for Each Ownership and Operational Models in Distribution System

## DISCUSSION

In this paper, we presented the indexes to evaluate the ownership and operational authority structure of the distribution network that were not covered in previous studies. VIU, LU, OU, and IDSO structures are evaluated using the proposed evaluation indexes. The result is shown on hexagonal diagram in Figure 2. Based on the evaluation results, policy maker can choose the appropriate structure of the DISCO that fits in its policy direction.

*Incentives to invest in network* and *fairness in connecting third party DER* are important indicators in increasing the connection of DERs. Active investment in distribution network leads to increased capacity in distribution network. The increased capacity enables more connection of DERs. Therefore, the structure with high score in *incentive of investment* is suitable in enlarging the connections of DER. The VIU, LU, and IDSO model with VIU having DER show high score on *incentives to invest in network*. *Fairness in connecting third party DER* is also important because discrimination in connection of DER can lead to delays in connection of third-party DER. The model with the highest score in *fairness in connecting third party DER* is OU model. And the LU and IDSO with VIU not having DER show medium scores in the index.

Operational fairness become important as the connection ratio of DER increases. Discrimination in operations lead

to a deterioration in profitability due to increased curtailment and a shrinkage of investment in DER. Therefore, high operational fairness is required to induce incentive of long-term investment of DER. OU and IDSO structures shows high scores on *fairness in distribution system operation*. Regardless of owning of DER by VIU, both IDSO structures show high score in *fairness in distribution system operation*.

This study has limitations in deriving the results through qualitative evaluation. Therefore, it is necessary to develop the research into quantitative research based on specific case studies and data in further study. In addition, since this study is approaching from a theoretical perspective, realistic conditions or practices should be studied more in practice.

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