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Tai-Ken Lu
Department of Electrical Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C., tklu@mail.ntou.edu.tw

Wen-Chi Chang
Department of Electrical Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

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Tai-Ken Lu and Wen-Chi Chang

Key words: Power intrachange mechanism, line congestion, efficiency analysis, purchase cost.

ABSTRACT

In recent years, the deregulation of power companies has been a subject of discussion in many countries. However, irrespective of the degree of deregulation of a power industry, its power systems still have the same basic structure for power generation, transmission, distribution and the end user. In most countries, the power industry has institutions dedicated to achieving improvements in its power systems in order to maintain reliable power supply. Power companies often establish power interchange support mechanisms with nearby power systems to ensure a stable power supply. One such mechanism is "power intrachange," wherein a power system can compensate for regional power shortages by purchasing the surplus electricity of a cogeneration system and/or from an independent power producer located inside or outside the region. Power intrachange can compensate for insufficient spinning reserve, line congestion, limited quantities of specific fuel, and high operational costs. In this paper, an executive model of power intrachange is studied and their efficiency analysis is conducted. Further, as an example, we use the high-fuel-cost gas turbine units that were activated in 2005 because of heavy load and line congestion in the northern area of Taiwan. After the calculations, we find that the Taiwan Power Company could not only solve the regional line congestion problem but also save 3,208.59 kNT$ by implementing the line congestion power intrachange mechanism when the line congestion occurred.

I. INTRODUCTION

In recent years, the deregulation of power companies has been a subject of discussion in many countries, and its significance and ramifications have been the subject of considerable analysis. However, irrespective of the degree of regulation, the basic structure of a power system for power generation, transmission, distribution and the end user remains the same. Moreover, in many countries, the power industry has institutions that are dedicated to bringing about improvements in the power system in order to maintain reliable power supply. Nevertheless, the demand often exceeds supply due to unpredictable factors such as delays in the construction of power plants, fuel supply problems, and drastic increases in power usage.

On such occasions, when the demand is greater than the supply, power companies often rely on power interchange support mechanisms with nearby power systems. Power interchange mechanisms can be basically divided into two types: generalized power interchange and power intrachange. The so-called generalized power interchange is a power support mechanism achieved by signing a contract with another power system to maintain power supply security between their different power systems. On the other hand, power intrachange implies that a power system can purchase the surplus electricity of a cogeneration system or from independent power producers (IPPs) located inside or outside the region where congestion occurs.

In recent years, the Taiwan Power Company (Taipower) has been aggressively trying to exploit all types of possible electric supply infrastructure in order to meet the increase in power demand. However, as a result of the increasing awareness regarding environmental protection, this has not been easy and has led to an imbalance in regional power systems, particularly in the northern regions of Taiwan. In the short term, Taipower continues to face risks of power shortage due to potential shortfalls in the supply of natural gas, delay in the commercial operation of a fourth nuclear power plant, and outage in the north-central 345 kV line N-2. In the long term, Taipower's power supply will be seriously influenced by a) whether the plans for constructing coal power plants can pass environmental assessments and b) the operation of the commercial operation of a fourth nuclear power plant.

Hence, Taipower should not only encourage growth in power generation by utilizing cogeneration systems but also introduce incentives to encourage privately owned utilities to supply more electricity to meet the demand of those regions where power shortage is predicted.

Paper submitted 10/08/10; accepted 01/04/12. Author for correspondence: Tai-Ken Lu (e-mail: tklu@mail.ntou.edu.tw).
Department of Electrical Engineering, National Taiwan Ocean University, Keelung, Taiwan, R.O.C.

Lu and Chang [7] proposed the power intrachange concept as a solution to the power supply imbalance problem, and proposed a method to estimate the technical ability for implementing power intrachange and the potential power generation based on the current domestic power demand and supply status. Subsequently, Lu and Chang [8] proposed a method to estimate the market value of power intrachange and a reasonable purchase price for implementing power intrachange among the seven time-segments of the Taipower system.

Huang and Yeh [3] proposed an assessment function after taking avoided cost, loss adjustment, and line upgradation adjustment into consideration in order to calculate a reasonable selling price for the electricity generated by cogeneration systems. Akeo Kuwahata used the extensive game model to analyze the interactions between utility and cogeneration in the pricing of purchased power and wheeling charges. By using simulations and their results, it was shown that in Japan, cogeneration can not only supply excess power during peak periods but also gain market advantage [5].

In 1988, Takeyoshi discussed the economic impact of IPPs from the viewpoint of the total generation cost of utilities and proposed that electric power utilities should purchase electricity from IPPs through competitive bidding based on the avoided cost of the corresponding generation of utilities [4].

Pribicevic *et al*. [11] presented a method for the optimal planning of both generation and market activities in municipal cogeneration systems by explicitly considering the inherent price in a new market. Post *et al*. [10] proposed the application of sequential sealed-bid and sealed-offer auctions to the pricing of electric power by using linear programming. Liu *et al*. [6] proposed an optimal method of optimal power flow in large interconnected power grids. The interchange information among regions is export price and boundary nodal bus phase angle. A Decentralized Solution to the DC-OPF of Interconnected Power Systems is discussed in previous studies [1, 2, 9, 13, 14].

Sekar *et al*. [12] presented a user-friendly software in modeling daily base case by including the peak power interchange, forecast loads, scheduled generator, and transmission line outages in North Amercain. In fact, two versions of this software have been developed with a full power interchange model and a decoupled power interchange model. The decoupled power interchange model is only concentrating on the southern security coordinators' power interchange to the north. The full power interchange model is including all the transactions in that peak hour.

In this paper, the executive model of power intrachange is discussed and their efficiency analysis is conducted. Basically, power intrachange units can be operated to compensate for, for example, a lack of spinning reserve, line congestion, limited supply of a specific fuel, and high operational costs.

Here, the entire power consumption data of Taipower system in 2005 will be used for the evaluation of purchase price and for the efficiency analysis of power intrachange when line congestion occurs.

II. EXECUTIVE MODEL OF POWER INTRACHANGE

Depending on the operational requirements of power intrachange, their executive models are divided into different types: economic, reliability, and emergency. The purposes, conditions, and procedures of performing these different types of power intrachange are described in the following sections.

1. Economy-Type Power Intrachange

The primary purpose of economy-type power intrachange is to decrease the overall generation cost of a power system. The reasonable purchase price of power intrachange units is designed on the basis of various time segments such as peak period and off-peak period [1]. Since the generation costs of many parts of the power intrachange units are lower than those of the system generating units, some of the power generation can be incorporated into the unit commitment, thereby decreasing the generation cost.

In economic dispatch, the power from economy-type power intrachange units is dispatched until their maximum limits are reached. Typically, such power intrachange units include coal-fired units, oil-fired units, and gas-fired units. On the basis of the difference in the generation costs of economy-type power intrachange units, their dispatch occurs in the following order: first, coal-fired units, then oil-fired units, and finally gas-fired units. Gas-fired units have lowest dispatch priority because they have the highest fuel cost per unit, and moreover, the amount of gas that can be supplied is also often limited.

2. Reliability-Type Power Intrachange

Reliability-type power intrachange can be divided into three types as follows: insufficient spinning reserve, line congestion, and limited specific fuel. The power system becomes a reliability problem when conditions such as either insufficient spinning reserve, line congestion, or limited specific fuel occurs. Currently, reliability-type power intrachange units play an extremely important role in increasing the reliability of a power system. The conditions and procedures for implementing a reliability-type power intrachange are described as follows:

1) Insufficient Spinning Reserve

The units, which serve as a spinning reserve, must consider units' ramp rates and the mobility of the operator of dispatch divisions. In order to assist a system to operate stably and reliably, the power generation of the power intrachange units is increased, and the power generation of utility-owned on-line units is lowered when the capacity of the spinning reserve becomes insufficient.

The on-line units of a power intrachange, especially in the case of those participating in economy-type units, have top dispatch priority. The operational conditions of power intrachange units depend on the predicted overall hours after which the capacity of the spinning reserve will become insufficient.

As mentioned above, the on-line units of power intrachange have top dispatch priority, faster ramp rate units have second priority, and off-line units have least priority. The operator dispatches the power intrachange units according to this priority in order to maintain the safety capacity of a spinning reserve when the spinning reserve is insufficient.

2) Line Congestion

The problems of line congestion can be divided into problems with transmission line and over-load of the main transformer. When congestion occurs, the imbalance between supply and demand in regional systems becomes more serious. In general, higher-generation-cost units belonging to or present in the regional area that is experiencing imbalance will be used to solve the problem of line congestion. However, simultaneously, the overall generation cost increases. This implies that starting lower-generation-cost power intrachange units is more efficient since it not only solves the imbalance problem but also avoids the starting of higher-generation-cost units that are utility-owned.

Basically, the economy-type units have top dispatch priority. The line-congestion-type units will be dispatched if all the economy-type units have already been operated and congestion still exists in the power system. As discussed above, the operation procedure of line-congestion-type units is in the following order: on-line units, faster ramp rate units, and off-line units.

3) Limited Specific Fuel

The so-called limited specific fuel implies that the supply of a certain specific fuel, such as gas, is limited because of the nature of the output, economic causes, or other reasons. Since this type of fuel-fired units is necessary for system dispatches such as frequency control units, the amount of the fuel must be sufficiently reserved and be used only when required. Presently, power intrachange units can be dispatched instead of parts of the specific fuel-fired units in order to reserve sufficient fuel. In limited-specific-fuel-type units, the operation procedures of the power intrachange units are identical to those in other types.

3. Emergency-Type Power Intrachange

Emergency-type power intrachange refer to the system forces used to purchase power generation from power intrachange units in order to avoid impacting the system when the spinning reserve is seriously insufficient. The so-called lower spinning reserve is the capacity of the spinning reserve within a safety percentage for the system, such as under 5% in the case of Taipower.

The emergency-type power intrachange units must be activated over a very short time period when the spinning reserve is seriously insufficient. In other words, the on-line units and faster ramp rate units are suitable as emergency-type power intrachange units. The operation procedure of the emergency-type power intrachange units in order is as follows: on-line units, faster ramp rate units, and off-line units.

Table 1. Symbols in the model.

Symbols	Mean	Unit
$F_i(P)$	fuel cost function ($) of the i-th unit	
λ_{sys}	incremental cost of the system	$/MW
P_{load}	system load	MW
P_{loss}	ystem loss	MW
Pf_{i}	loss penalty factor	
P_i	output of the i-th unit	MW
Z	system total generation cost	$
n	total number of generators	
λ_i	generation cost function of unit i	MW
P_{Gi}	generation output of unit i	MW
P_{Li}	power of load i	MW
m	total number of buses	
$P_{Gi\,\max}$	maximum generation output of unit i	MW
$P_{Gi\,\min}$	minimum generation output of unit i	MW
P_{ik}	power flow from bus i to bus k	MW
$P_{ik\,\max}$	maximum capacity from bus i to bus k	MW
θ_i	angle of bus i	radian
θ_k	angle of bus k	radian
x_{ik}	impedance of transmission line from bus i to bus k	Ω

III. PUBLISHED PRICE AND EFFICIENCY ANALYSIS OF POWER INTRACHANGE

It is necessary to evaluate the value of the power intrachange when it is applied to the economy-type, reliability-type, and emergency-type models. The economic dispatch model, which is proposed in [1], is adopted to estimate the value of energy and power of the power intrachange. The model is described as follows, and the variables in the present article are listed in Table 1.

$$pf_i \frac{dF_i(P_i)}{dP_i} = \lambda_{sys} \tag{1}$$

$$\sum_{i=1}^{N} P_i = P_{load} + P_{loss} \tag{2}$$

$$P_{i\min} \le P_i \le P_{i\max} \tag{3}$$

The estimative method is suitable for all types of power intrachange types other than line congestion. The DC power flow is employed in the value estimation method of the line-congestion-type power intrachange because of the line capacity limitation. The mathematical model is established below.

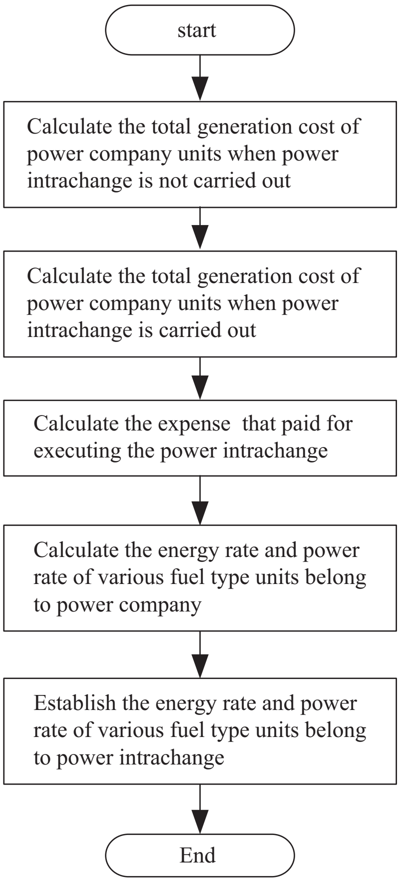

Fig. 1. The procedure of establishing the purchase price of the power intrachange.

Objective function:

$$\text{Minimize } Z = \sum_{i=1}^{n} \lambda_i P_{Gi} \tag{4}$$

Constrains:

Power balance limit:

$$\sum_{i=1}^{n} P_{Gi} = \sum_{j=1}^{m} P_{Lj} \tag{5}$$

Unit generation limits:

$$P_{Gi\min} \le P_{Gi} \le P_{Gi\max} \tag{6}$$

Capacity limitation of transmission lines:

$$-P_{ik\max} \le P_{ik} = \frac{1}{x_{ik}}\left[\theta_i - \theta_k\right] \le P_{ik\max} \tag{7}$$

1. Establishing the Purchase Price of Power Intrachange

The purchase price of the power intrachange is established based on two parameters—energy rate and capacity rate.

Table 2. Symbols in the equations establishing the purchase price of the power intrachange.

Symbols	Mean	Unit
ΔC	usable expense paid for executing the power intrachange	$
T_{GC}	total generation cost of utility-owned units when power intrachange is not performed	$
T_{GCI}	total generation cost of power company units when power intrachange is performed	$
CR^{type}	capacity rate of various fuel type	$/MW
T_{GC}^{type}	total generation cost of various fuel type units	$/MWh
T_{FC}^{type}	total fuel cost of various fuel type units	$/MWh
T_{G}^{type}	total generation capacity of various fuel type units	MWh
type	fuel type	
$AVFC^{type}$	energy rate of various fuel type	$/MWh
FC_i^{type}	fuel cost of the i-th unit for a certain fuel type	$/MWh
P_{Gi}^{type}	power generation of the i-th unit for a certain fuel type	MWh
q	number of a certain fuel type units	
$\Delta AVFC^{type}$	weighting factor of the energy rate of various fuel type units	
η	payback coefficient	
r	number of fuel type	
P_{Cont}^{type}	demand of various fuel type units	MW
E^{type}	total power generation of various fuel type units	MWh

Fig. 1 shows the procedures for establishing the purchase price of a power intrachange. The variables in the equations are shown in Table 2.

1) Calculation of the Total Generation Cost of Power Company Units when Power Intrachange is Not Performed

The statement that "the so-called power intrachange is not performed" implies that the amount of power generation is completely supplied by utility-owned units in the system. The total generation cost (T_{GC}) is the sum of the individual generation costs of utility-owned units according to the economic dispatch. The average generation cost (AV_{GC}) and average fuel cost (AV_{FC}) can be calculated if the total generation cost, total generation capacity (T_G), and total fuel cost (T_{FC}) were offered by the utility. The total fixed cost (T_{CC}) is equal to the total generation cost (T_{GC}) minus the total fuel cost (T_{FC}). The value obtained when the total fixed cost (T_{CC}) is divided by the total generation capacity (T_G) represents the average fixed cost. Since the maintenance cost is increased and is involved in the average fixed cost when the units operate, the fixed cost should be separately apportioned into the energy rate and capacity rate. In other words, 35% of the average fixed cost will be the energy rate, and 65% of the average fixed cost will be the capacity rate. Finally, the energy rate of purchasing power intrachange is 35% of the average fixed cost plus average fuel cost, and the capacity rate of purchasing power intrachange is 65% of the average fixed cost.

2) Calculation of the Total Generation Cost of Power Company Units When Power Intrachange Is Performed

The total generation cost of utility-owned units (T_{GCI}) includes the purchase cost of power intrachange. The purchase cost of power intrachange can be calculated from the energy rate and capacity rate, which is published by government organizations such as the Bureau of Energy, Ministry of Economic Affairs (MOEA), Taiwan.

3) Calculation of the Cost for Executing the Power Intrachange

The expense, calculated using Eq. (8), is paid for executing the power intrachange. In other words, the expense given below represents the funds for purchasing the power generation of power intrachange.

$$\Delta C = T_{GC} - T_{GCI} \tag{8}$$

4) Calculation of the Energy Rate and Capacity Rate of Various Fuel-Type Units Belonging to the Power Company

A. Capacity rate of various fuel-type units

The capacity rate of various fuel-type units is calculated by Eq. (9) as follows:

$$CR^{type} = 0.65 \times \frac{T_{GC}^{type} - T_{FC}^{type}}{T_G^{type}} \tag{9}$$

B. Energy rate of various fuel-type units

The energy rate between the generating units is a little diversified because of the different fuels used. In order to obtain a reasonable purchase price for various fuel-type units, their energy rate is 35% of the average fixed cost plus the fuel's average fuel cost. The equation for such a calculation is shown below:

$$AVFC^{type} = \frac{\sum_{i=1}^{q} FC_i^{type}}{\sum_{i=1}^{q} P_{Gi}^{type}} + 0.35 \times \frac{T_{GC}^{type} - T_{FC}^{type}}{T_G^{type}} \tag{10}$$

5) Establishing the Energy Rate and Capacity Rate of Various Fuel-Type Power Intrachange Units

A. Capacity rate of various fuel-type power intrachange units

The calculation of the capacity rate of various fuel-type power intrachange units is identical to the calculations using Eq. (9).

B. Energy rate of various fuel-type power intrachange units

There are two steps to calculate the energy rate of various fuel-type power intrachange units (IFC^{type}). First, compute the weighting factor of the energy rate of various fuel-type units. The calculation is as follows:

$$\Delta AVFC^{type} = \frac{AVFC^{type}}{\sum_{i=1}^{r} AVFC_i^{type}} \times \Delta C \times \eta \tag{11}$$

The first part of Eq. (11) is the ratio of a certain fuel-type unit's average referred fuel cost to the total amount of various fuel-type units' average fuel cost. The payback coefficient (η) implies the proportion that a power company purchases extra power from a cogeneration system based on profit-sharing.

Second, the energy rate of various fuel-type power intrachange units (IFC^{type}) represents the energy rate of various fuel-type utility-owned units ($AVFC^{type}$) plus the weighting factor of the energy rate of various fuel-type units. The equation for such calculations is shown below:

$$IFC^{type} = AVFC^{type} + \Delta AVFC^{type} \tag{12}$$

The procedure for establishing the purchase price of the power intrachange is very suitable for certain fuel types or periods and a power company would want to purchase extra power from power intrachange units.

2. Efficiency Analysis of Power Intrachange

The total generation cost of various fuel-type units can be calculated when the corresponding capacity rate and energy rate are calculated. The equation for this calculation is shown below:

$$T_{GCI}^{type} = CR^{type} \times P_{Cont}^{type} + AVFC^{type} \times E^{type} \tag{13}$$

According to Eq. (13), the difference (ΔE) between the total generation cost with power intrachange and the total generation cost without power intrachange is used to estimate the economic efficiency of implementing power intrachange. It is more efficient to purchase power generation from power intrachange units if the value is positive; conversely, power generation need not be purchased from the power intrachange units if the value is negative.

IV. RESULTS

Here, we use the entire power consumption data of the Taipower system in 2005 for establishing the purchase price and efficiency analysis of power intrachange units when line congestion occurs in some regional systems.

From the abovementioned data, we find that high-fuel-cost gas turbine units were activated because of heavy load and

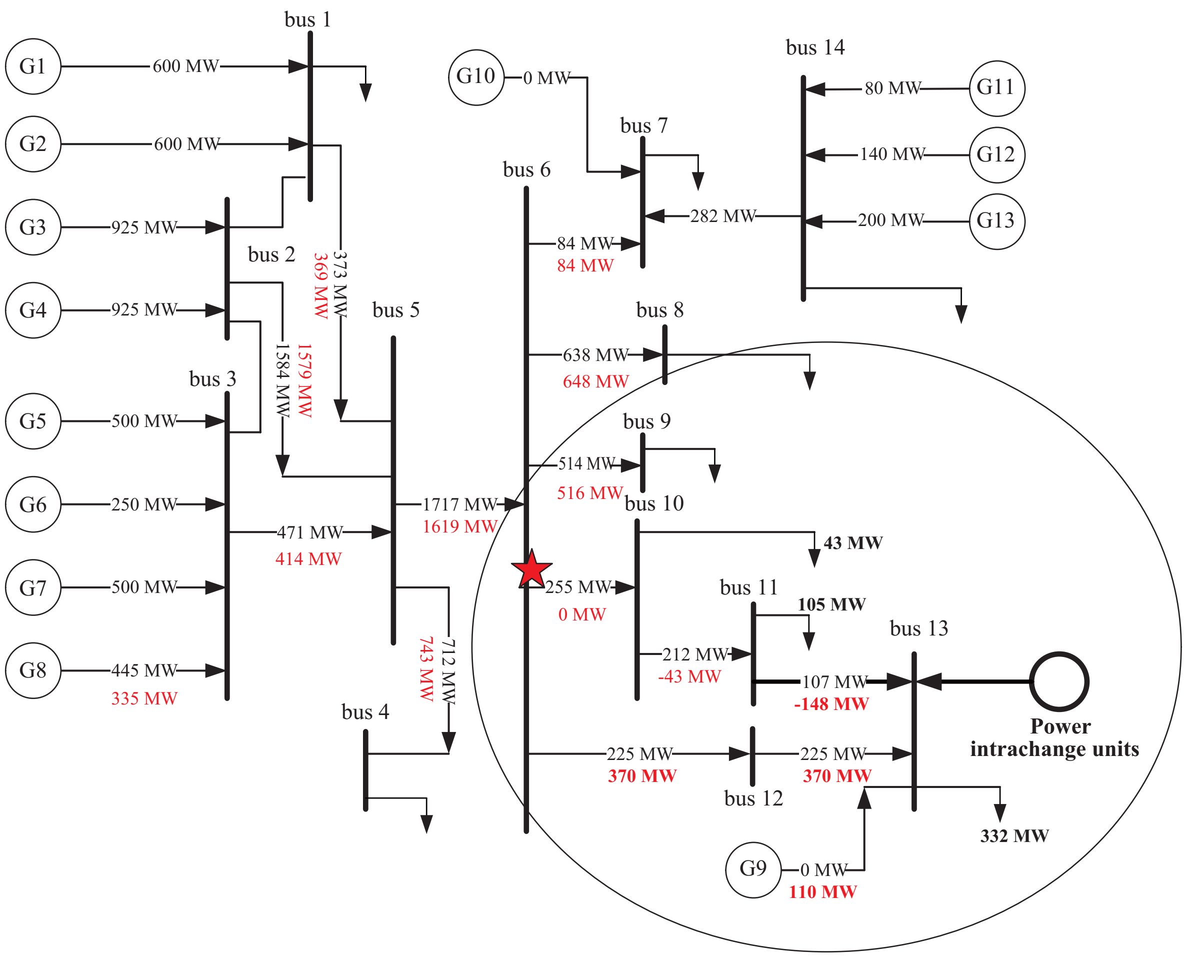

Fig. 2. 14 buses system single-line diagram.

line congestion in the northern region. As a result, the total generation cost of Taipower increased. We will now apply the proposed method to the simplified 14-buses single-line diagram of a certain extra high-voltage substation in northern Taiwan, as shown in Fig. 2. The system has 14 buses, 4 base-load generating units (G1, G2, G3, and G4), 7 variable generating units (G5, G6, G7, G8, G11, G12, and G13), and 2 gas turbine units (G9 and G10). The transmission line data is shown in Table 3. Under normal operation conditions, the total amounts of power generated from the variable generating units and gas turbine units are listed in Table 4.

The simulation case is described as follows. First, it is assumed that the line between bus 6 and bus 10 is outage. Second, it is assumed that line congestion is present in some regions in the line between bus 6 and bus 12, such as in the circular section shown in Fig. 2. Third, high-fuel-cost gas turbine units must be activated to match the demands of this region.

We will apply the proposed method to the simplified 14-buses system and establish the purchase price and efficiency analysis of the line-congestion power intrachange unit. The following is the procedure for the estimation.

Table 3. The transmission line data.

Line (bus to bus)	Flow with operation (MW)	Flow with congestion (MW)	Line Limit (MW)
1-5	373	369	2,142
2-5	1,584	1,579	4,284
3-5	471	414	2,142
5-4	712	743	4,282
5-6	1,717	1619	2,000
6-7	84	84	740
6-8	638	648	2,232
6-9	514	516	870
6-10	255	0	370
6-12	225	370	370
10-11	212	-43	288
11-13	107	-148	288
12-13	225	370	370

1. Calculation of the Total Generation Cost of Generating Unit Without Line Congestion

After the calculation, the total power generation and total generation cost of the generating unit other than the base-load

Table 4. The total power generation and total generation cost of the generating unit without line congestion.

	Power generation (kWh)	Fuel cost (NT$/kWh)	Generation cost (k NT$)
G5	500,000	1.95	975
G6	250,000	2.04	510
G7	500,000	2.02	1,010
G8	445,867	2.03	905.11
G11	80,000	0.84	67.2
G12	140,000	0.84	117.6
G13	200,000	0.84	168
G9	0	31.4	0
G10	0	31.4	0
Total	2,115,867		3,752.91

Table 5. The total power generation and total generation cost of the generating unit with line congestion.

	Power generation (kWh)	Fuel cost (NT$/kWh)	Generation cost (k NT$)
G5	500,000	1.95	975
G6	250,000	2.04	510
G7	500,000	2.02	1,010
G8	335,037	2.03	680.13
G11	80,000	0.84	67.2
G12	140,000	0.84	117.6
G13	200,000	0.84	168
G9	110,830	31.4	3,480.06
G10	0	31.4	0
Total	2,115,867		7,007.99

generating units are 2,115.86 MWh and 3,752.91 kNT$, respectively. Detailed data is shown in Table 4.

2. Calculation of the Total Generation Cost of a Generating Unit with Line Congestion

As shown in Fig. 2, the load in bus 10 and bus 12 is 480.83 MW. The line limit capacity from bus 6 to bus 12 is 370 MW. In other words, the supply is not sufficient for meeting the demands when the line between bus 6 and bus 10 is outage. The gas turbine units (G9) should be activated immediately and 110.83 MW must be supplied to meet the load. Simultaneously, the power generation of the variable generating units (G8) is decreased to 110.83 MW. After the calculations, the total power generation and total generation cost of the generating unit are found to be 2,115.86 MWh and 7,007.99 kNT$, respectively. The detailed data is shown in Table 5.

3. Calculation of the Expenses Paid for Executing the Power Intrachange

From Eq. (8), the expenses paid for executing the power intrachange is 7,007.99 kNT$ – 3,752.91 kNT$ = 3,255.08 kNT$. The average generation cost (ΔC) can be calculated as the expense divided by the power generation of the gas turbine units. The average generation cost is the maximum price for purchasing the power intrachange when line congestion occurs. After the calculation, the average generation cost (ΔC) is obtained as 29.37 NT$/kWh.

4. Calculation of the Energy Rate and Capacity Rate of Various Fuel-Type Units

As mentioned above, the coal-fired units and oil-fired units are basic generating units of the power intrachange. The energy rate and capacity rate are established based on the economic-type power intrachange. Assuming a payback coefficient (η) of 20%, the energy rate and capacity rate are calculated as given below.

1) Energy Rate

The energy rates of the coal-fired units and oil-fired units belonging to the economic-type power intrachange are 0.8347 (NT$/kWh) and 2.7893 (NT$/kWh), respectively, and the proportions accordingly are 23.03% and 76.97%, respectively. From Eq. (11), the weighting factors of the energy rate distributed to the coal-fired units and oil-fired units are 1.3529 (NT$/kWh) and 4.5211 (NT$/kWh), respectively. Finally, from the calculations given in Eq. (12), the energy rates of the coal-fired units and oil-fired units of power intrachange units are 2.1876 (0.8347 + 1.3529) NT$/kWh and 7.3104 (2.7893 + 4.5211) NT$/kWh, respectively. In other words, the energy rates of purchasing power intrachange units, including coal-fired units and oil-fired units, are 2.1876 NT$/kWh and 7.3104 NT$/kWh, respectively.

2) Capacity Rate

The calculation of the capacity rate belonging to the coal-fired units and oil-fired units is based on the capacity rate of the economic-type power intrachange. After the calculations, the capacity rates of the coal-fired units and oil-fired units are 0.1799 (NT$/kWh) and 0.1198 (NT$/kWh), respectively.

5. Efficiency Analysis

It is assumed that the generation capacity for purchases from both coal-fired units and oil-fired units is 55.415 MW and the payback coefficient (η) is 20%. There are three steps for calculating the total generation cost of purchasing the line-congestion power intrachange units.

First, we calculate the power generation cost of the generating units belong to Taipower when the power intrachange mechanism is executed. After the calculations, this cost becomes 3,527.93 kNT$. Second, the generation cost of purchasing from coal-fired units and oil-fired units can be calculated when the corresponding energy rate and capacity rate have been evaluated. From Eq. (13), the corresponding costs are 65.6 kNT$ and 205.87 kNT$, respectively. Finally, the total generation cost of purchasing the line-congestion power intrachange units for adding to the mentioned cost is 3,799.40 kNT$.

Table 6. The economic analysis of implementing line congestion power intrachange mechanism under the different payback coefficient.

Payback coefficient (%)	Power intrachange unit	Purchase rate			Total generation cost (kNT$)		Efficiency analysis (kNT$)
		Capacity rate (NT$/kW)	Energy rate (NT$/kWh)		Without power intrachange	With power intrachange	
			Without power intrachange	With power intrachange			
20	Coal-fired Oil-fired	0.1799 0.1198	0.8347 2.7893	2.1876 7.3104	7007.99	3,799.40	3,208.59
50	Coal-fired Oil-fired	0.1799 0.1198	0.8347 2.7893	4.2170 14.0920		4,043.53	2,964.46

As mentioned above, the difference (ΔE) = 7,007.99 kNT$ – 3,799.40 kNT$ = 3,208.59 kNT$. In other words, Taipower could have saved 3,208.59 kNT$ by implementing line-congestion power intrachange mechanism when line congestion occurred in the regional system.

Table 6 shows the economic analysis of implementing line-congestion power intrachange mechanism with a different payback coefficient. The result shows that it is more efficient to implement line-congestion power intrachange mechanism when line congestion occurs in the regional system.

V. CONCLUSIONS

"Power intrachange" is a mechanism by which power systems can purchase the surplus electricity of cogeneration systems and independent power producers from inside or outside the affected region to compensate for temporary regional shortages. On the basis of the type of operation of the power intrachange, the executive models are divided into three types: economy, reliability, and emergency. This paper primarily explores the executive model and the efficiency analysis of power intrachange. As an example, we use the activation of high-fuel-cost gas turbine units because of the heavy load and line congestion in the northern area of Taiwan in 2005. After the calculations, we find that when regional system line congestion occurred in 2005, Taipower could not only have solved the regional line congestion problem but also saved 3,208.59 kNT$ by implementing the line-congestion power intrachange mechanism.

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