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CO_2 배출량제약을 고려한 최적전원구성

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The Best Generation Mix considering CO2 Air Pollution Constraint

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Abstract - A new approach considering CO2 air pollution constraints in the long-term generation mix is proposed under uncertain circumstances. A characteristic feature of the presented approach in this paper is what effects give the air pollution constraints in long term best generation mix. Best generation mix problem is formulated by linear programming with fuel and construction cost minimization with load growth, reliability (reserve margin rate) and air pollutionconstraints. The proposed method accommodates the operation of pumped-storage generator. It was assumed in this study that the construction planning of the hydro power plants is given separately from the other generation plans. The effectiveness of the proposed approach is demonstrated by applying to the best generation mix problem of KEPCO-system, which contains nuclear, coal, LNG, oil and pumped-storage hydro plant multi-years.

1. Introduction

There is a global trend towards liberalization and privatization of the electricity supply industry. This is coupled with growing environmental awareness and increasing prospects ratification of the Kyoto Protocol.[1] Electricity is the indispensable form of energy in modern societies. Its demand has been increasing more and more quantity, quality and reliable at minimize production cost. The restructuring of electricity market has been moving from monopolistic to competitive that split generation, transmission and distribution sector in power system into GENCO, TRANSCO and DISCO respectively.[2] In this paper, a new approach for the long-term generation mix with multi-criteria consideringair pollution constraints, which are not only SO2 and NOXbut also CO2 emission limitations, under the uncertain circumstances is proposed using linear programming [4-5]. The effectiveness of the proposed approach is demonstrated by applying to the best generation mix problem of KEPCO-system, which contains nuclear, coal, LNG, oil and pumped-storage hydro plantmulti-years.This case study in this paper is mainly focused on CO2 emission limitation effect in the best generation mix. The method can accommodate the operation of the pumped-storage generator which has a relationship with operation of nuclear power plant with some strict for load following [6].

2. The LP Formulation of Best Generation Mix

2.1 Problem statement

The system for the proposed method can be modeled as shown in Fig. 1.

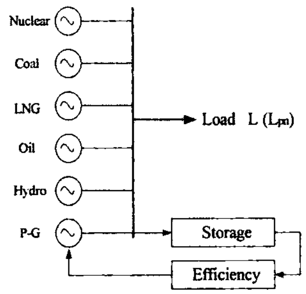


Fig. 1 A system model for the proposed method

2.2 Objective functions

$$Minimize\ Z = \sum_{n=1}^{N}\sum_{i=1}^{NG} K_{cin} d_{in} \alpha_i \Delta x_{in} + \sum_{n=1}^{N}\sum_{i=1}^{NG} K_{fin} f_{in} y_{in} = F(\Delta x_{in}, y_{in}) \quad (1)$$

where, i: unit type number (1 for nuclear, 2 for coal, 3 for LNG, 4 for oil, and 5 for pumped-storage generators are specified in this paper)

N: number of total study stage year

NG: number of unit type

K_{cin}= ((1+eci)/(1+r))n T

K_{fin}= ((1+efi)/(1+r))n T

e_{ci}: apparent escalation rate of construction materials of i-unit

e_{fi}: apparent escalation rate of fuel of i-unit

r: discount rate

T: step size years of study years

d_{in}: construction cost of the i-unit in n year

f_{in}: marginal fuel cost of the i-unit in n year [\$/MWh]

i: annual expenses rate of the i-unit

x_{in}: construction capacity of the i-unit in n year [MW]

y_{in}: generation capacity of the i-unit in n year [MWh]

2.3 Constraints

1) Installed capacity constraint

$$\sum_{i=1}^{NG}(x_{in} + \Delta x_{in}) \geq L_n^P(1+R_n) - HYD_n \quad n = 1 \sim N \quad (2)$$

where,Rn: supply reserve rate in n year. [p.u]

HYDn: capacity of hydro generator in n year. It is assumed that the HYDn is given in this study.

2) Energy constraint of demand

$$\sum_{i=1}^{NG} y_{in} \geq (L_n^P + L_n^B) \times 8760/2 + V_n - HYD_n \times 8760 \times CF_H \quad n = 1 \sim N \tag{3}$$

where, LPn: peak load at n year

LBn: base load at n year

Vn: the added demand energy is caused by pumped-storage generator

CF H: average capacity factor of hydro generator

3) Production energy constraint of generation system

$$y_{in} \leq (x_{in} + \Delta x_{in}) \times 8760 \times CF_i \quad i = 1 \sim NG,\ n = 1 \sim N \tag{4}$$

where, CFi: average capacity factor of the i-unit

4) Capacity constraint in initial year

$$x_{i1=EX_i} \quad i = 1 \sim NG \tag{5}$$

where, EXi: capacity of the i- existing unit

5) Constraint of mutual relationship between existing generator capacity and new generator capacity (state equation)

$$x_{in+1} = x_{in} + \Delta x_{in+1} \quad i = 1 \sim NG,\ n = 1 \sim N \tag{6}$$

6) Energy constraint of LNG thermal plant

$$y_{3n} \geq LEP_{\min} \quad i = 1 \sim N \tag{7}$$

where, LEPmin$n$: LNG thermal generator production energy for LNG minimum due to consumption in n year

7) Constraints of reservoir capacity of pumped-storage generator

$$V_n \leq (x_{5n} + \Delta x_{5n}) \times 8760 \times CF_5 \quad i = 1 \sim N \tag{8}$$

where, PSM: pumped-storage maximum possible time per day of pumped-storage generator

8) Energy balance constraints between pumped-storage and pumped-generator

$$y_{5n} = \eta_{pg} \times V_n \tag{9}$$

where, pg: efficiency of pumped-storage generator

9) No load following power constraints of nuclear power plant

$$(x_{1n} + \Delta x_{1n+1}) \leq L_n^B + (x_{5n} + \Delta x_{5n+1}) / \eta_{pg} \tag{10}$$

10) No load following energy constraints of nuclear power plant

$$y_{1n} = (x_{1n} + \Delta x_{1n}) \times 8760 \times CF_i \tag{11}$$

11) Upper-lower constraints of new unit capacity

$$\Delta X_{\min in} \leq \Delta x_{in} \leq \Delta X_{\max x \text{ in}} \tag{12}$$

where, Xmin in and Xmaxx in are minimum and maximum capacity of new unit at n years(period) respectively.

12) CO2 air pollution constraint

$$\sum_{i=1}^{NG} CO2_{in} \rho_i y_{in} \leq CO2_{MAXn} \tag{13}$$

where,

$CO2in$: CO2 density of the i- unit in n year [ppm/Ton]

CO2MAXn : maximum quantity of CO2 permitted in n year [Ton/yr]

i: fuel consumption rate of the i- unit [Ton/MWh]

13) SOX air pollution constraint

$$\sum_{i=1}^{NG} SO2_{in} \rho_i y_{in} \leq SO2_{MAXn} \tag{14}$$

where, $SOXin$: SOX density of the i- unit in n year [ppm/Ton]

SOXMAXn : maximum quantity of SOX permitted in n year [Ton/yr]

14) NOX air pollution constrain

$$\sum_{i=1}^{NG} NOX_{in} \rho_i y_{in} \leq NOX_{MAXn} \tag{15}$$

where,$NOXi,n$: NOX density of the i- unit in n year [ppm/Ton]

NOXMAXn : maximum quantity of NOX permitted in n year [Ton/yr]

3. Case Studies

The step size of planning year is assumed as five years (T=5). The maximum, minimum load and hydro capacity in standard years are listed in table 1.The characteristics and economic data are summarized in table 2 and table4, respectively.

Table 1. Maximum load, minimum load, and hydro plant at standard years

Years	Peak load LP [MW]	Base load LB [MW]	Hydro [MW]	LEP (103Ton)
2006	48,108	30,340	1,800	--
2011	57,340	34,200	2,000	4500
2016	69,500	42,500	2,200	5500
2021	78,200	47,500	2,400	6500
2026	87,000	53,500	2,600	7500

Table 2. Maximum load, minimum load, and hydro plant at standard years

Gen.Type	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Density [ppm/Ton] CO2,SO2, NOx
Nucl.	16,715	145.0	2	6.8	1	19	80	--	
Coal	17,465	100.0	1	13.8	1	17	70	0.4030	700 450 500
LNG	14,313	85.0	1	21.5	1	17	65	0.0500	450 200 300
Oil	4,308	75.0	1	120.0	4	17	55	0.0234	600 200 100
P-G	2,000	45.0	1	0.0	0	13	30	--	

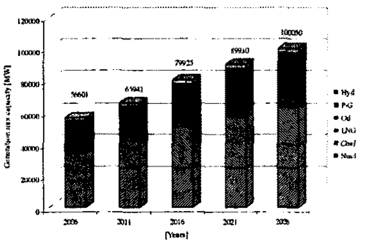
(where: AER means the apparent escalation rate and the discount rate is assumed as 10%)

{(1) Initial capacity [MW] (2) Fixed charge [105won/kW] (3) AER of fixed charge [%] (4) Marginal fuel cost [Won/kW] (5) AER of fuel cost [%] (6) Annual cost rate [%] (7) Capacity factor [%] (8) Fuel cons rate [Ton/MWh]}

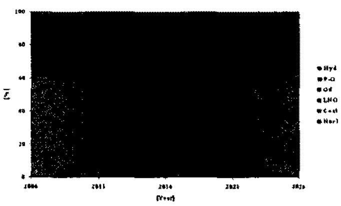
Table 3. Maximum permissible limitation of air pollution emission (103 [Ton/yr])

Air pollution	2011	2016	2021	2026
CO2	60	60	60	60
SO2	40	40	40	40
NOX	40	40	40	40

The results yield that the mix of nuclear power plants is increasing and that of coal power plants is decreasing. Fig. 2 and Fig. 3 shows total capacity and percent ratio results for conventional method and proposed method considering air pollution constraints.

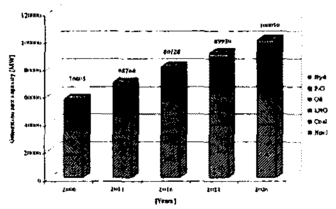


(a) Total capacity

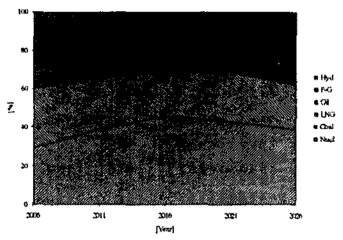


(b) Percent ratio

Fig.2. Best generation mix by Conventional method



(a) Total capacity



(b) Percent ratio

Fig. 3. Best generation mix by proposed method with CO2 air pollution constraint

The total cost evaluation given in Table 4 shows that there is much different total cost between the cases not considering air pollution constraints and the case considering air pollution constraints. As the air pollution constraints are considered, the mix of nuclear power plant is growing up and the total cost is increasing.

Table 4. Total cost evaluation of best generation mix in the two cases. [Billion Won]

	Construction Cost	Operation Cost	Total Cost
Conventional method	3,463.10	7,751.29	11,214.39
Mix with CO2 APC	4,065.65	7,221.03	11,286.68

4. Conclusions

In this paper, a new approach for the long-term generation mix with multi-criteria considering air pollution constraints, which are not only SO2and NOX but also CO2 emission limitations, under the uncertain circumstances is proposed using linear programming. The effectiveness of the proposed approach is demonstrated by applying to the best generation mix problem of KEPCO-system, which contains nuclear, coal, LNG, oil and pumped-storage hydro plantmulti-years. The CO2 air pollution constraint is more strict, the nuclear or LNG power plant construction is recommended as shown in the case study although the total cost is increasing. This case study in this paper is mainly focused on CO2 emission limitation effect in the best generation mix. The method can accommodate the operation of the pumped-storage generator which has a relationship with operation of nuclear power plant with some strict for load following.

5. Acknowledgement

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