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8.

3

g_i i MW $i = 1;2;...;8$
 g_{i0} i MW
 l_i j MW $j = 1;2;...;6$
 a_{ij} j i
 b_j j
 m_j j MW
 r_j j
 \hat{j} j
 v_i i MW /
 g_{mi} i MW
 $p_i(g_i)$ i g_i /MWh
 p_M : /MWh
 PL MW
 E
 t 1/4

4

4.1

4.2

[1]

32

15

4.3

1.

2.

3.

4.4

1.

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2.

0

3.

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5.

0

0

1

4.5

1.

$$\sum_{i=1}^8 g_i = PL$$

2.

$$g_{i0} + v_i \cdot t \cdot g_i \cdot g_{i0} + v_i \cdot t; \quad i = 1; 2; \dots; 8$$

3.

$$g_i \in g_{mi}; \quad i = 1; 2; \dots; 8$$

4.

$$j l_j j_i \quad m_j < 0; \quad j = 1; 2; \dots; 6;$$

5.

0

$$j l_j j_i \quad (1 + r_j) m_j \in 0; \quad j = 1; 2; \dots; 6$$

5

5.1

$$\begin{matrix} & & 33 \\ 1 & & 2 \end{matrix}$$

5.1.1

$$l_j = \sum_{i=1}^8 a_{ij} g_i + "j \quad (1)$$

$$l_j = \sum_{i=1}^8 a_{ij} g_i + b_j + "j \quad (2)$$

$$"j \gg N^i 0; \mathbb{H}_j^2 \mathbb{C}$$

$$j = 1; 2; \dots; 6$$

$$a_{ij} \quad b_j \quad 0 \quad 32$$

(1)

$$L_j = \begin{matrix} 3 \\ l_j^{(0)}; l_j^{(1)}; \dots; l_j^{(32)} \end{matrix}^T; \quad G = \begin{matrix} \textcircled{O} \\ \textcircled{B} \\ \textcircled{A} \end{matrix} \begin{matrix} g_1^{(0)} & g_2^{(0)} & \dots & g_8^{(0)} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \end{matrix} \begin{matrix} 1 \\ \textcircled{C} \\ \textcircled{A} \end{matrix}$$

$$A_j = (a_{1j}; a_{2j}; \dots; a_{8j})^T; \quad E_j = \begin{matrix} 3 \\ g_1^{(32)} & g_2^{(32)} & \dots & g_8^{(32)} \end{matrix}^T$$

$$G^T G A_j = G^T L_j \quad (3)$$

$$(3) \quad A_j \quad A_j$$

$$\begin{matrix} (2), \\ \overline{A_j} = [b_j; A_j] \end{matrix} \quad \begin{matrix} \overline{G} = [N; G] \\ A_j \quad \overline{A_j} \end{matrix} \quad G \quad N = (1; 1; \dots; 1)_{1 \times 33}^T \quad 1$$

5.1.2

$$l_j \quad g_1; g_2; \dots; g_8$$

$$\textcircled{R} \quad j \quad (j = 1; 2; \dots; 6)$$

$$H_0 : a_{1j} = a_{2j} = a_{3j} = a_{4j} = a_{5j} = a_{6j} = a_{7j} = a_{8j} = 0$$

$H_1 : i = 1;2;:::;8 \quad a_{ij} \neq 0$

$F \quad R^2 \quad [2]$

5.1.3

MATLAB

@5%

1 2

(2)

(1)

(2)

"

"

0

(2)

" "

1.

"

"

2.

(2)

(1)

5.2

" "

5.2.1

1.

$p_{i;k}^{(0)}$

$p_M^{(0)} (p_{i;k}^{(0)} < p_M^{(0)})$

i

k

$g_{i;k}^{(1)}$

$g_{i;k}^{(0)} > g_{i;k}^{(1)}$

$$E_{i;k} = (p_M^{(0)} i p_{i;k}^{(0)}) (g_{i;k}^{(0)} i g_{i;k}^{(1)}) t \quad (4)$$

2.

$0 \quad p_{i;k}^{(0)} > p_M^{(0)}$

i

$k \quad g_{i;k}^{(1)} > 0$

$g_{i;k}^{(0)} =$

$$E_{i;k} = (p_{i;k}^{(0)} i p_M^{(0)}) (g_{i;k}^{(1)} i g_{i;k}^{(0)}) t = (p_M^{(0)} i p_{i;k}^{(0)}) (g_{i;k}^{(0)} i g_{i;k}^{(1)}) t \quad (5)$$

$$E^0 = \prod_{i,k} E_{i;k}^0$$

$$E = {}^o t E^0$$

Step3 $flag_i = 0$ $g_i = \sum_{i=1}^P g_i$ i

Step2 $g = \sum_{i=1}^P g_i$

Step4 $g = PL$ g_i i

$g > PL$ $flag_i = 1$ $g < PL$ $flag_i = -1$

Step5

Step5 $g < PL$ $flag_i \neq 1$

Step2 $g > PL$ $flag_i \neq 1$

Step2

5.4

5.4.1

" "

1.

$$l_j = \sum_{i=1}^P a_{ij} g_i + b_j \quad j|j|j| m_j < 0; \quad j = 1; 2; \dots; 6 \quad (6)$$

2.

$$\begin{aligned} & \min E \\ & \sum_{i=1}^P g_i = PL; \\ \text{s.t. } & j|j|j| m_j < 0; \\ & g_{i0} - v_i \leq t \leq g_i \leq g_{i0} + v_i \leq t; \\ & g_i \leq g_{mi} \end{aligned} \quad (7)$$

7

7

3.

7

$$j = \frac{j l_j j = m_j i - 1}{r_j} \quad j = (1 + r_j \hat{j}) m_j$$

" "

(a)

$$\begin{aligned} & \min_{\hat{j}} \max_{j} \hat{j} \\ & \text{s.t.} \quad g_i = PL \\ & \quad j l_j j i (1 + \hat{j} r_j) m_j < 0 \\ & \quad g_{i0} i v_i t \leq g_i \leq g_{i0} + v_i t \\ & \quad g_i \leq g_{mi} \\ & \quad \hat{j} \leq 1 \end{aligned} \quad (8)$$

(8) $f_j^a g_j^b = 1$

(b) (8)

(8)

$$\begin{aligned} & \min_{\hat{j}} E \\ & \text{s.t.} \quad g_i = PL \\ & \quad j l_j j i (1 + \hat{j} r_j) m_j < 0 \\ & \quad g_{i0} i v_i t \leq g_i \leq g_{i0} + v_i t \\ & \quad g_i \leq g_{mi} \\ & \quad \hat{j} \leq \hat{j}^a \end{aligned} \quad (9)$$

(9) (8) (9) (9)

4.

(8)

$$\begin{aligned} & \max_{\hat{j}} g_i \\ & \text{s.t.} \quad g_{i0} i v_i t \leq g_i \leq g_{i0} + v_i t \\ & \quad g_i \leq g_{mi} \\ & \quad j l_j j i (1 + r_j) m_j < 0 \end{aligned} \quad (10)$$

5.4.2

1. (7)

$$E = \max_i f(p_i(g_i) \mid p_M^{(0)}) \notin PLg;$$

$$G \quad \max_i p_i(g_i)$$

$$j \neq i \quad a_{ij} \neq a_{ji} \quad i = 1; 2; \dots; 8$$

$$a_{ij} \neq$$

$$\min_{i=1}^n \max_{j=1}^n p_i(g_i)$$

$$g_i = PL;$$

$$\text{s.t.} \quad l_j \mid m_j < 0;$$

$$g_{i0} \mid v_i \notin t \subset g_i \subset g_{i0} + v_i \notin t$$

$$g_i \subset g_{mi}$$

MATLAB

[3]

0

(a)

(b)

[6]

(c)

i.

ii.

$$l_j > m_j \quad a_{ij} \neq f a_{ij} g \quad j$$

$$G_0 \quad p_M^{(0)}$$

Step1 G_0

0 G_0 i g_i^*

Step2 $g_i \leq g_i^*$

$\max_i g_i$

$\sum_{j=1}^8 l_j \leq m_j$

s.t. $g_{i0} + v_i t \leq g_i \leq g_{i0} + v_i t$

$g_i \leq g_i^*$

Step3 $g_i > PL$

Step4 $\sum_i g_i = PL$

Step2

MATLAB

4 5

2.

(a) 8

8

$\sum_{i=1}^8 p_i \min_i g_i = PL$

$l_j + (1 + r_j)m_j < 0$

s.t. $g_{i0} + v_i t \leq g_i \leq g_{i0} + v_i t$

$g_i \leq g_{mi}$

$\hat{r}_j \leq \hat{r}^*$

$0 \leq \hat{r} \leq 1$

15 $(g_1, g_2, \dots, g_8; \hat{r}_1, \hat{r}_2, \dots, \hat{r}_6; \hat{r})$

(b) 9

7

$\sum_{i=1}^8 p_i \max_i p_i(g_i)$

$\sum_{i=1}^8 p_i \min_i g_i = PL$

$l_j + (1 + r_j)m_j < 0$

s.t. $g_{i0} + v_i t \leq g_i \leq g_{i0} + v_i t$

$g_i \leq g_{mi}$

$\hat{r}_j \leq \hat{r}_j^*$

3.

10

$\max_i g_i$

$$\begin{aligned} & \sum_{i=1}^8 g_{i0} - v_i \leq t \leq g_{i0} + v_i \leq t \\ \text{s.t. } & g_i \leq g_{mi} \\ & l_j - (1 + r_j)m_j \leq 0 \\ & (g_1, g_2, \dots, g_8) \end{aligned}$$

5.5

6

6.1

6.1.1 (1)

1

	$a_{ij}(i = 1; 2 \leq j \leq 8)(10^i \text{ }^2)$	R^2	F	$\sigma^0: 10^i \text{ }^{10}$
1	[19.382,32.389,14.084,24.792,10.393,32.064,6.7494,13.063]	0.7307	9.6882	85053
2	[7.7276,46.115,10.453,18.548,24.079,12.39,-8.3441,25.564]	0.6213	5.8596	4196100.
3	[-17.89 -21.49,-24.34,-13.62,-0.322,-19.396,5.098,-33.156]	0.8008	14.357	240.85
4	[4.3359,9.4364,26.689,6.9081,7.905,14.548,10.693,16.917]	0.8750	24.996	8.7098
5	[13.411,58.101,4.1388,11.312,9.0764,30.982,-6.9572,15.007]	0.6036	5.4375	6979500
6	[35.901,24.627,1.823,23.298,18.844,21.738,10.674,14.494]	0.7797	12.638	7992.1

$$1 \quad j \quad j \quad 1 \quad j \quad \sigma^0$$

2

	$a_{ij}(i = 1; 2 \leq j \leq 8)(10^i \text{ }^2)$	b_j	R^2	F	σ^0
1	[8.2607,4.7764,5.2794,11.986,-2.5705,12.165,12.199,-0.15179]	110.48	0.99944	5376.8	0
2	[-5.4717,12.75,0.014644,3.3244,8.6667,-11.269,-1.8644, 9.8528]	131.35	0.99957	6970.2	0
3	[-6.9387,6.1985,-15.65,-0.9871,12.467,0.23561,-0.2787, -20.119]	-109	0.99986	21788	0
4	[-3.4632,-10.278,20.504,-2.0882,-1.2018,0.56932,14.522, 7.6336]	77.612	0.99988	24424	0
5	[0.03271,24.283,-6.471,-4.1202,-6.5452,7.0026,-0.38961, -0.917]	133.13	0.99953	6433.9	0
6	[23.757,-6.0693,-7.8055,9.2897,4.6634,-0.029128,16.64, 0.0388]	120.85	0.99981	16029	0

6.1.2 (2)

6.2

6.3

982.4MW 3

6.4

982.4MW 3

4 5

1 2

6.5

78

1052.8MW

6

3

	1	2	3	4	5	6	7	8
	120	73	180	80	125	125	81.1	90
	150	79	180	99.5	125	140	95	113.9
	252	300	233	302	215	252	260	303
	33	15	48	19.5	27	30	21	27
	30	6	0	19.5	0	15	13.9	23.9
	303							

4

	1	2	3	4	5	6
	165	150	160	155	132	162
	173.3047	141.0049	-150.9235	120.9114	136.8265	168.519
	8.3047	-8.9951	-9.0765	-34.0886	4.8265	6.519

5

	[153,86.87, 228, 90.1124, 152, 95.3222, 60.1,117]
	[33,15,48,19.5,27,30,21,27]
	[33,15,48,10.11,27,-29.69,-21,27]
	[165,150,160,155,132,162]
	[165,150,155.26,124.51,131.51,159.53]
	495
1	3183.1
2	47155

6

	1	2	3	4	5	6	7	8
	120	73	180	80	125	125	81.1	90
	150	81	218.2	99.5	135	150	102.1	117
	252	320	356	302	310	305	306	303
	356							

7

	1	2	3	4	5	6
	165	150	160	155	132	162
	177.24	141.17	156.15	129.74	134.83	167.06
	12.24	-8.83	-3.85	-25.26	2.83	5.06

8

	[153,88,228,99.5,152,155,60.3,117]
	[489,495,356,302,510,380,120,303]
	[33,15,48,19.5,27,30,21,27]
	[33,15,48,19.5,27,30,20.8,27]
	[165,150,160,155,132,162]
	[173.4093,143.5833,155.2113,124.6828,135.2969,160.4221]
	[39.2%,12.3%,4.25%,-85.16%,30.23%,19.29%]
	510
1	1962.3
2	40533

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Hu man

[7] Pool

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A Management Model for Transmission Congestion in Power Market

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Abstract: In this paper, on the basis of an open and competitive market, model is developed to study the management of transmission congestion in an independent power system. Firstly, under the assumption of local linearization, the approximate formula for the relation of the power flow distribution to the machine output is derived by multivariate linear regression. Both the models with and without constant-term are considered and tested. Furthermore, according to the knowledge from power system analysis, we demonstrate that the model with the constant-term is more reasonable. Considering the effect of the congestion adjustment, we design two rules for calculating congestion cost and make detailed comparison between them. According to the transaction rule of the power market and accounting for the computation efficiency as well, we use the recursion strategy to figure out a simple and feasible method for the preliminary scheme of output allocation. This article proposes a four-stage computation strategy for the congestion adjustment, which is: congestion check, pre-scheme adjustment, margin transmission and load limitation. In the first stage, a group of inequalities are judged; the second stage is to program with the objective of minimum congestion cost; in the third stage, our first target is the minimum occupancy of the margin, then the objective is the lowest congestion cost while the occupancy remains the same if no less than. In the last stage, assuring the lowest security level, the objective is maximum output. After simplification, all models are linear except the second one, which is a staircase function maxi-min programming subjected to linear constraint condition. Also, we find that the procedure is most efficient if the Hu man tree is used as the decision tree. In this case, only a few simple rules are needed to determine which stage ought to be carried on instead of doing step by step. Last but not the least, we study the programming performance of staircase function from the perspective of generalized function, and we propose two simple heuristic algorithms and other suggestions for the optimization problem whose objective is staircase function. The methods proposed in this paper are clear and efficient. However, for the lack of the professional knowledge, we do not give reasonable congestion management method for some current typical patterns of the power market.

Keywords: power congestion management; multivariate linear regression; programming flows by stages; efficient programming flow of Hu man decision tree; heuristic algorithms