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Dynamic Economic Load Dispatch of Electric Power System Using Direct Method

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Abstract

The main objective of the dynamic economic dispatch problem is to determine the optimal schedule of all generating units so as to meet the required load demand and losses at minimum operating cost while satisfying ramp rate limits. This paper presents an application of direct method for solving the problem to find the optimum dispatch solution. While the approaches required are the cost of a generating unit in the form of a quadratic function and estimated losses through B-loss coefficient. The proposed method has been evaluated 6-unit system with considering the generator constraints, ramp rate limits. The obtained results of the proposed method have been in line with expectations. Where the results of the method are effective and efficient and can be competed with the others.

Keywords: Optimal schedule; ramp rate limits, estimated losses, Quadratic objective function.

INTRODUCTION

Scheduling of generating units, units, to meet loads of the system that is always changing have to involve ramp rate limits of each unit and consider losses of the system, losses. Involvement of the ramp rate limits is to guarantee that the optimal results for the purpose of scheduling of the units can be implemented properly to meet dynamic system loads. A few methods have published in solving an economic dispatch, EDP, namely:

A. Conventional methods

These methods have been published such as iteration lambda method, gradient method, Newton method, linear method and dynamic programming method [1]-[4]. They work by the iterative process so that can take a large enough computing time. For the large scale of the EDP, the addition of the computing time will be seen significantly. One thing that must be payed attention here, namely sometimes they cannot achieve convergence in the process of iteration.

B. Methods based on artificial intelligent concept

These methods are such as artificial neural network [5], particle swarm optimization, PSO, [6]-[8] and genetic algorithm [9]-[11]. A major problem associated with these techniques is that appropriate control parameters are required. Sometimes these techniques take large computational time due to improper selection of the control parameters.

The methods that were mentioned above, the completions are always the through iterative process so they can take a large computing time. This paper will propose a method without iteration, i.e. direct method that has been studied by [12], so that is expected to reduce the computing time and simpler so easier to be applied. We expect that this proposed method will be more effective and efficient for a dynamic economic dispatch, especially the EDP with large scale. But this developed technic is limited by the cost function of the unit in the quadratic form, and losses are approached through an estimate with using B-loss coefficients.

By the approaches, formulations of the proposed method have been derived with very clear. Then, it is verified with doing a test for a system that consists of 6 units through a numerical study. This numeric study is purposed to see comparisons of the results between the proposed method and the other methods.

METHODOLOGY

A. Formulation of A Dynamic Economic Dispatch

The primary objective of an EDP is to minimize the total fuel cost of power plants subjected to the operating constraints of a power system. In general, the EDP can be formulated mathematically as a constrained optimization problem with an objective function of the form (1).

$$F_T = \sum_{i=1}^{n} F_i(P_i) \qquad (1)$$

Where *FT* is the total fuel cost of the system ($/hr), n is the total number of units and *Fi* (*Pi*) is the operating fuel cost of unit i ($/hr). In this study, the fuel cost function of the unit is expressed as a quadratic function as given in (2).

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \qquad (2)$$

Where *Pi* is the real output power of unit i (MW), *ai* ,*bi* and *ci* are the cost coefficients of unit i. The minimization of the EDP problem is subjected to the following constraints :

- *Real Power Balance Constraint*

For power balance, an equality constraint should be satisfied. The total generated power should be equal to the total load demand plus the losses. The active power balance is given by in (3).

$$\sum_{i=1}^{n} P_i = P_D + P_L \qquad (3)$$

Where, P_D is the total load demand (MW), P_L is the losses (MW). The losses is assumed as a quadratic function of output powers of the generator units that can be approximated in the form (4) using B-loss coefficients, $B_{ij,}$

$$P_L(t) = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i(t) B_{ij} P_j(t) \qquad (4)$$

- *Generator Power Limit Constraint*

The generation output power of each unit should lie between the minimum and maximum limits. The inequality constraint for each generator can be expressed as in (5).

$$P_{i,\min} \le P_i \le P_{i,\max} \qquad (5)$$

Where *Pi*,min and *Pi*,max are the minimum and maximum power outputs of generator i (MW), respectively. The maximum output power of generator is limited by thermal consideration and minimum power generation is limited by the flame instability of a boiler.

- *Ramp Rate Limit Constraints*

The generator constraints due to ramp rate limits of generating units are given as in (6) and (7).

1) As Generation Increases:

$$P_i(t) - P_i(t-1) \le UR_i \qquad (6)$$

2) As Generation Decreases:

$$P_i(t-1) - P_i(t) \le DR_i \qquad (7)$$

Therefore the generator power limit constraints can be modified as in (8).

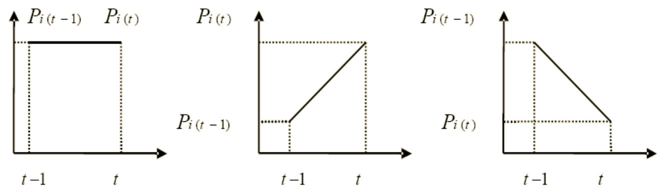
$$\max(P_{i,\min}, P_i(t-1) - DR_i) \le P_i(t) \le \min(P_{i,\max}, P_i(t-1) + UR_i) \qquad (8)$$

From (8), the limits of minimum and maximum output powers of generating units at time t will be limited under the conditions based on modification as in (9).

$$P_{i,\min}(t) = \max(P_{i,\min}, P_i(t-1) - DR_i) \qquad (9)$$

$$P_{i,ma}(t) = \max(P_{i,\max}, P_i(t-1) + UR_i) \qquad (10)$$

Where *Pi* (*t*) is the output power of generating unit i (MW) in the time t, *Pi* (*t* −1) is the output power of generating unit i (MW) in the previous time, time t-1, *URi* is the up ramp limit of generating unit i (MW/time-period) and *DRi* is the down ramp limit of generating unit i (MW/time-period). While the ramp rate limits of the generating units with all possible cases are shown in Figure 1.



(a) (b) (c)

Figure 1. Ramp rate limits of the generating units

B. Dynamic Economic Dispatch Problem

A dynamic economic dispatch problem, DEDP, is to meet ramp rate limits, (6) and (7), in the power changes of each unit from t-1 to t. So, the DEDP can be expressed by in (11).

Objective: $F_T(t) = \sum_{i=1}^{n} F_i(P_i(t))$

Subject to : $\sum_{i=1}^{n} P_i(t) = P_D(t) + P_L(t)$ (11)

$$P_{i,\min}(t) \le P_i(t) \le P_{i,\max}(t)$$

C. Completion of DEDP

In this paper is created the research for the objective function in quadratic form and estimated losses through B-loss coefficients, like the problem expressed in the (11). This problem will be solved in two stages. Stage I does optimization without the power limits of units. Stage II evaluates the optimal results of stage I against violent of the ramp rate limits for each unit. The following is a detailed explanation of the DEDP settlement.

- *Units with Fixed Power*

From three possibilities of ramp rate, Fig. 1, Fig. 1a is the unit that does not change the power from time t-1 to t so that satisfies Pi,o(t-1)=Pi,o(t). Then, this unit is removed in the optimization process and followed with updating total load, P_D, through (12).

$$P_{D,New}(t) = P_{D,Old}(t) - \sum_{i=1}^{m} P_{i,o}(t) \qquad (12)$$

Where m is number of the units with fixed power.

- *Direct Method*

For the quadratic objective function such as (2) and assume P_L(t) constant, then LaGrange multiplier (lambda) at time t is:

$$\lambda(t) = b_i + 2c_i P_i(t) \qquad (13)$$

Or,

$$P_i(t) = \frac{\lambda(t) - b_i}{2c_i} \qquad (14)$$

Where *Pi(t)* is optimal power for unit-i at time t, $\lambda(t)$ is LaGrange multiplier at time t, b_i is price linear parameter for unit-i ($/MWH), c_i is price quadratic parameter for unit-i ($/MWH2). So for n-unit generators are:

$$\sum_{i=1}^{n} P_i(t) = \sum_{i=1}^{n} \frac{\lambda(t) - b_i}{2c_i} \qquad (15)$$

From the last equation, the value of lambda can be obtained directly as expressed by (16) below.

$$\lambda(t) = \frac{P_D(t) + P_L(t) + \sum_{i=1}^{n} \frac{b_i}{2c_i}}{\sum_{i=1}^{n} \frac{1}{2c_i}} \qquad (16)$$

Equation (16) shows the optimization of completion directly or without through iterative process, so the convergence is always able to be guaranteed. After lambda value has been determined and continued to determine optimal power unit with the (14). Then, to be done evaluation against the minimum and maximum power limits at time t to be able optimal solution, $P_{i,o}(t)$.

- *Loss Estimation*

Determining losses in the electric power system is very complex because it depends on the network structure, load and generating distributions. In this study, it is estimated with (17) below.

$$P_L(t) = P_L(t-1)\left(1 + \frac{P_D(t) - P_D(t-1)}{P_D(t)}\right) \qquad (17)$$

While losses in the system at time t-1, $P_L(t-1)$, based on (4) can be approximated in the form of (18).

$$P_L(t-1) = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i(t-1) B_{ij} P_j(t-1) \qquad (18)$$

Where *Bij* is the transmission loss coefficient matrix, *Pi* and *Pj* are the power generation of *i* and *j* units.

- *Evaluation of the direct results*

In the direct method still does not yet involves the generating power constraints so the results can violate those constraints. So, these results must be evaluated against the constraints. The evaluation is done with the following provisions.

- For units violate the maximum constraint, namely:

  $P_{i,o}(t) > P_{i,max}(t)$, set $P_{i,o}(t)=P_{i,max}(t)$

- For units violate the minimum constraint, namely:

  $P_{i,o}(t) < P_{i,min}(t)$, set $P_{i,o}(t)=P_{i,min}(t)$

- For units do not violate the minimum and maximum constraints, namely:

  $P_{i,min}(t) < P_{i,o}(t) < P_{i,max}(t)$, set $P_{i,o}(t)=P_{i,o}(t)$

D. Algorithm of the Proposed Method

The following is the steps of completion for DEDP with the proposed method that has been descripted above.

1. Calculate P_L(t) through (17).
2. Remove the unit is not changed and update load by the (12).
3. Update generating power limits through the (9) and (10).
4. Calculate $P_i(t)$.
5. If $P_i(t)>P_{i,max}(t)$, then $P_{i,o}(t)=P_{i,max}(t)$, update :

   $P_D(t)=P_D(t)-P_{i,o}(t)$, remove unit i and continue step 3.
6. If $P_i(t)<P_{i,min}(t)$, then $P_{i,o}(t)=P_{i,min}(t)$, update :

   $P_D(t)=P_D(t)-P_{i,o}(t)$, remove unit i and continue step 3.
7. Set $P_{i,o}(t)=P_i(t)$ for not violate the generating power limits.
8. Results.
9. Stop.

NUMERICAL STUDY

To verify the effectiveness of the proposed method, a six-unit power generating plant was tested. The Algorithm of the method has been implemented in the program using FORTRAN. It is applied to 6 units with generating power constraints and ramp rate limits. The fuel cost data and ramp rate limits of the six units were given in Table I. The load demand for 24 hours is given in Table II. While B-loss coefficients of six units system are given in (19).

$$B_{ij} = 10^{-3}\begin{bmatrix} 1.7 & 1.2 & 0.7 & -0.1 & -0.5 & -0.2 \\ 1.2 & 1.4 & 0.9 & 0.1 & -0.6 & -0.1 \\ 0.7 & 0.9 & 3.1 & 0.0 & -0.1 & -0.6 \\ -0.1 & 0.1 & 0.0 & 0.24 & -0.6 & -0.8 \\ -0.5 & -0.6 & -0.1 & -0.6 & 12.9 & -0.2 \\ -0.2 & -0.1 & -0.6 & -0.8 & -0.2 & 15.0 \end{bmatrix} \quad (19)$$

Table I: Fuel Cost Coefficients and Ramp Rate Limits of Six Units System

Unit	a_i (\$)	b_i (\$/MW)	c_i (\$/MW^2)	$P_{i,min}$ (MW)	$P_{i,max}$ (MW)	UR_i (MW/h)	UD_i (MW/h)
1	240	7.0	0.007	100	500	80	120
2	200	10.0	0.0095	50	200	50	90
3	220	8.5	0.009	80	300	65	100
4	200	11.0	0.009	50	150	50	90
5	220	10.5	0.008	50	200	50	90
6	190	12.0	0.0075	50	120	50	90

Table II. Load Demand for 24 Hours of Six Units System

Time (h)	Load (MW)	Time (h)	Load (MW)	Time (h)	Load (MW)	Time (h)	Load (MW)
1	955	7	989	13	1190	19	1159
2	942	8	1023	14	1251	20	1092
3	935	9	1126	15	1263	21	1023
4	930	10	1150	16	1250	22	984
5	935	11	1201	17	1221	23	975
6	965	12	1235	18	1202	24	960

Table III. Output Power, Losses and Total Fuel Cost for 24 Hours by Proposed Method of 6-Units System

HR.	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_6 (MW)	LOSS (MW)	FUEL COST (\$)
1	382.7	124.1	214.3	75.4	116.1	50.0	7.57	11422.13
2	379.5	121.8	211.9	73.0	113.3	50.0	7.48	11260.68
3	377.8	120.5	210.5	71.6	111.8	50.0	7.34	11172.85
4	376.6	119.6	209.6	70.7	110.8	50.0	7.26	11110.41
5	377.8	120.5	210.5	71.6	111.8	50.0	7.26	11171.89
6	384.6	125.5	215.8	76.9	117.8	50.0	7.51	11520.40
7	390.9	130.1	220.7	81.8	123.3	50.0	7.91	11848.44
8	399.2	136.2	227.1	88.3	130.5	50.0	8.37	12280.27
9	421.7	152.8	244.7	105.8	150.2	60.3	9.49	13608.24
10	426.6	156.4	248.5	109.6	154.5	64.8	10.49	13931.66
11	436.7	163.9	256.4	117.5	163.4	74.3	11.15	14605.54
12	443.5	168.9	261.6	122.8	169.4	80.6	11.89	15062.77
13	434.7	162.4	254.8	115.9	161.6	72.4	11.74	14469.20
14	446.7	171.3	264.1	125.2	172.1	83.6	11.96	15275.45
15	449.2	173.1	266.0	127.1	174.3	85.9	12.60	15443.21
16	446.6	171.2	264.0	125.2	172.0	83.5	12.59	15270.52
17	440.9	167.0	259.6	120.7	167.0	78.1	12.19	14882.04
18	437.1	164.1	256.6	117.7	163.7	74.6	11.75	14626.54
19	428.5	157.8	250.0	111.1	156.2	66.6	11.18	14057.48
20	415.2	148.0	239.6	100.7	144.5	54.2	10.21	13180.36
21	399.4	136.4	227.3	88.4	130.7	50.0	9.13	12289.81
22	389.8	129.3	219.9	81.0	122.3	50.0	8.30	11791.05
23	387.6	127.7	218.1	79.2	120.4	50.0	7.95	11674.66
24	383.9	125.0	215.3	76.4	117.2	50.0	7.76	11486.33
Total							**231.11**	**313441.90**

Table III gives the optimal scheduling of all generating units, and total fuel cost for 24 hours by using proposed method. While Table IV loads the same results as Table III based on the genetic algorithm, GA, which the values are copied from [13].

DISCUSSION

From numerical study shows that the proposed method can give the optimal scheduling calculation very satisfactory, where the results were loaded in Table III. While Table IV shows the results of the GA method for the same case that will be used as a comparison. When both methods are compared, generally the results are shown in Table V. From the table is seen that the proposed method gives the total fuel cost is slightly bigger, i.e. $401.0 or 0.128%. However, if it is checked the losses with using B-loss coefficients in (4) for the power of the units in Table IV, for example at time t=1, obtained losses =7.42 MW. While losses in Table IV at the time are 6.58 MW. So, losses are less than the actual 0.84 MW or 11.2%. If this loss difference is considered, then the proposed method will be able competition with the GA method.

Based on the study [13] stated that Lambda Iteration Method will reach the convergent point in the range 1500-2000 iterations, and the GA and PSO Methods in the range 30-50 iterations. This shows that the methods in reach the convergent point must always be through the iteration processes so that will be able to take the computing time. While the proposed method is without iteration so the computing time can be ascertained will be very small when compared with the others.

Table IV. Output Power, Power Losses and Total Fuel Cost for 24 Hours by GA. of 6-Units System

Hr.	P_1 (MW)	P_2 (MW)	P_3 (MW)	P_4 (MW)	P_5 (MW)	P_6 (MW)	Loss (MW)	Fuel cost ($)
1	378.4	118.4	210.7	85.4	118.4	50.0	6.58	11411.42
2	373.2	116.0	207.8	84.7	116.4	50.0	6.38	11249.19
3	371.0	114.8	206.1	83.7	115.3	50.0	6.28	11162.06
4	369.3	113.8	205.1	82.9	114.8	50.0	6.21	11099.99
5	371.0	114.8	206.1	83.7	115.3	50.0	6.28	11162.06
6	381.3	119.8	212.1	86.5	119.7	50.0	6.69	11511.66
7	388.9	125.0	217.1	90.8	123.9	50.0	7.06	11838.99
8	395.8	132.8	222.0	97.7	126.3	55.5	7.38	12270.42
9	422.5	147.3	239.5	114.3	138.0	72.7	8.57	13599.96
10	427.1	153.0	243.5	118.8	140.0	76.2	8.86	13914.33
11	438.9	161.9	252.0	128.5	145.8	83.1	9.51	14588.41
12	446.2	166.8	257.8	134.6	150.4	89.0	9.95	15042.04
13	436.9	160.1	250.1	126.2	144.2	81.5	9.37	14442.43
14	450.2	169.5	260.1	136.7	152.7	91.7	10.18	15256.81
15	452.5	171.9	261.6	139.6	154.2	93.2	10.33	15418.34
16	450.0	169.4	259.9	136.5	152.6	91.5	10.16	15243.36
17	443.0	164.9	255.7	131.9	148.2	86.7	9.76	14854.86
18	439.1	162.1	252.2	128.7	145.9	83.2	9.52	14601.71
19	428.9	154.9	244.5	120.8	141.1	77.4	8.96	14032.65
20	411.9	142.0	236.1	108.4	135.3	66.2	8.20	13157.46
21	395.8	132.8	222.0	97.7	126.3	55.5	7.38	12270.42
22	387.9	124.1	215.9	89.8	123.0	50.0	6.99	11775.86
23	385.4	122.1	214.6	88.1	121.5	50.0	6.87	11662.42
24	380.3	119.0	211.7	86.2	119.2	50.0	6.65	11474.06
Total Fuel Cost ($)								313040.90

Table V. Loss and Total Fuel Cost Comparison between 2 Methods of 6-Units System

Method	Loss(MW)	Total Fuel Cost ($)
Genetic Algorithm (GA)	194.12	313040.90
Proposed Method	231.11	313441.90

CONCLUSION

A method for the optimal scheduling with involving power generating limits, ramp rate limits, and losses, has been proposed in this paper. This method is simple and without iteration process, so that can reduce significantly the computing time. One other advantage of the method, it will always be convergent, easy to be implemented and can work effectively and efficiently for the large scale. Verification of the method with six generating units has been tested with very satisfactory results, Table III. The proposed method can be competed with the other methods, like GA method with the results in Table IV. The values of both tables are slightly different.

REFERENCES

[1] A .J. Wood and B.F. Wollenberg, "Power Generation, operation, and control", John Wiley and Sons., New York, 1984.

[2] M. Salama, "Economic control for a generation in the thermal power system, Energy Conversion and Management", 40, 1999, pp. 669-681.

[3] IEEE Committee Report, "Present practices in the economic operation of power systems", IEEE Trans. Power Appa. Syst., PAS-90, 1971, pp. 1768-1775.

[4] G. Ratandeep, C Rashmi, C. Vikas and S. Nitin, "Optimal Load Dispatch Using B-Coefficients", International Journal of Emerging Trends in Electrical and Electronics (IJETEE – ISSN: 2320-9569) Vol. 3, Issue. 1, May-2013.

[5] J. Nanda, A. Sachan, L. Pradhan M.L. Kothari, A. Koteswara Rao, "Application of artificial neural network to economic load dispatch", IEEE Trans. Power Systems, vol. 22, 1997.

[6] Z. L. Gaing, "Constrained dynamic economic dispatch solution using particle swarm optimization", IEEE Power Engineering Society General Meeting, 2004, pp. 153-158.

[7] J. B. Park, K. S. Lee, J. R. Shin and K. Y. Lee, "A particle swarm optimization for economic dispatch with nonsmooth cost functions", IEEE Trans. Power Syst, 20, February (1), 2005, pp. 34-42.

[8] D. C. Walters and G. B. Sheble, "Genetic algorithm solution of economic dispatch with valve-point loading", IEEE Trans. Power Syst., 8 August (3), 1993, pp. 1325-1332.

[9] D. N. Jeyakumar, T. Jayabarathi and T. Raghunathan,

"Particle swarm optimization for various types of economic dispatch problems", Elec. Power Energy Syst, 28, 2006, pp. 36-42.

[10] J. Tippayachai, W. Ongsakul and I. Ngamroo, "Parallel micro genetic algorithm for constrained economic dispatch", IEEE Trans. Power Syst., 17 August (3), 2003, PP. 790-797.

[11] Bakirtzis, et. al. "Genetic algorithm solution to the economic dispatch problem", IEEE Proc. Generation, Transmission and Distribution, vol.141, no.4, July 1994, pp. 377-382.

[12] H. Zein, Y. Sabri, A. Mashar, "Implementation of Electricity Competition Framework with Economic Dispatch Direct Method", Telkomnika. 2012; 10(4): 667-674.

[13] W. M. Mansour, et al., "Dynamic Economic Load Dispatch of Thermal Power System Using Genetic Algorithm", IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498, Vol.3, No.2, April 2013.

[14] P. H. Chen and H. C. Chang, "Large-scale economic dispatch approach by genetic algorithm", IEEE Trans. on Power Systems, vol. 10, no. 4, November 1995, pp. 1918-1926.

[15] Y. H. Song, F, R. Morgen, and D.T.Y. Cheng, "Comparison studies of genetic algorithms in power system economic dispatch", Power System Technology, vol. 19, no. 3, 38. Mar. 1995, pp. 28-33.

[16] G. B. Sheble and K. Brittig, "Refined genetic algorithm-economic dispatch example", IEEE Trans. on Power Systems, vol. 10 ,no.1, Feb. 1995, pp. 117-124.

[17] J. Raharjo, A. Soeprijanto, H. Zein, "Multi Dimension of Coarse to Fine Search Method Development for Solving Economic Dispatch", Indonesian Journal of Electrical Engineering and Computer Science Vol. 3, No. 1, July 2016, pp. 1 ~ 9

[18] H. Shahinzadeh, N. Azadani, A.N. Jannesari, "Applications of Particle Swarm Optimization Algorithm to Solving the Economic Load Dispatch of Units in Power Systems with Valve Point Effects". International Journal of Electrical and Computer Engineering (IJECE). 2014; 4(6): 858-867.

[19] K.Y. Lee, M.A. El-Sharkawi, "Tutorial on Modern Heuristic Optimization Techniques with Applications to Power Systems", IEEE Power Engineering Society, 2013.

[20] S. Bhupender, S. Shivani, N. Ajay, "Particle Swarm Optimization and Genetic Algorithm based Optimal Power Flow Solutions, International Journal of Application or Innovation in Engineering & Management". 2013; 2(7): 307-315.

[21] G. Ratandeep, C Rashmi, C. Vikas and S. Nitin, "Optimal Load Dispatch Using B-Coeficients", International Journal of Emerging Trends in Electrical and Electronics (IJETEE – ISSN: 2320-9569) Vol. 3, Issue. 1, May-2013.

[22] M.V.P. Sevugarathinam, T. Keppanagowder, "Considering transmission loss for an economic dispatch problem without valve-point loading using an EP-EPSO Algorithm", Turk J Elec Eng & Comp Sci, Vol.20, No.Sup.2, 2012.

[23] Jangkung Raharjo, Adi Soeprijanto, Hermagasantos Zein,"Novel Method to Solve Economic Dispatch Scheduling for Large-Scale Power System", International Journal of Applied Research, ISSN 0973-4562 Vol. 12, Number 22, 2017, pp. 12500-12509.