Power Reserve Management For Power System Using Security Constraints

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Abstract: ***In this paper economic load dispatch problem and various optimization techniques are discussed and finally the proposed lambda iteration optimization technique has been used to solve the ELD problem for the system considering 10 units of generation. The results obtained were satisfactory for minimizing the total fuel cost for the 24 hours of operation while taking care of different constraints. For an isolated or interconnected power system reliable operation needs an adequate generating capacity that has to be available at all times while maintaining the required frequency so as to avoid loss of determining the control area's minimum reserve requirements. For a power system operation to be safe and reliable, spinning reserve capacity is one of the important task that needs to be calculated. In order to meet diverse needs, electrical power plays a central role in the modern world. It is therefore very necessary that the electrical power produced is efficiently transmitted and distributed so as to satisfy the demand for power. The most critical problem of optimization is the problem of Economic Load Dispatch (ELD).***

Keywords: Economic load dispatch (ELD), Unit Commitment (UC), spinning reserve, Optimization, ramp rate, Dynamic Programming, Lambda Iteration, Linear Programming, Newton Method

1. INTRODUCTION

As the power system's size is getting increased day by day due to the increased level of penetration of renewable energy sources which directly effects on the system stability, due to frequency changes. So considering the security constraints becomes necessary while dealing with the system security. Operating reserve is one of the most important requirements in the present day power system which directly affects the system dynamic stability. It increases the system reliability during load forecasting error, generating unit failure, scheduled or forced outages and local area protection. Reserved power is the extra amount of power used during any power shortage. Power supply reliability depends upon certain parameters: changes in the configuration and the structure of the power system, including power system control parameters; power reserve, transmission capacity reserve for the transmission lines, available fuel stock at thermal power plants etc.[1].

2. LITERATURE REVIEW

The power reserve management in the power system is one of the important factor for increasing the reliability of the power system at optimal cost. For increasing the reliability of the power system reserve capacity needs to be increased which would directly increase the cost of the production.[2]. So without managing the reserve capacity of the power system the increase in the reliability will increase the cost. So we need to manage it when and how much power reserves we need. For the power to be supplied with max reliability at minimal cost, Economic Load Dispatch and Unit commitment are the two ways by which this can be achieved. Various researchers have proposed different methodologies/techniques for the optimization of Economic Load Dispatch and Unit Commitment Problems. There are various AI techniques proposed by the researchers for finding the optimal solution to the economic load dispatch and unit commitment problem. Theofanis et.al.[3], presented the firefly algorithm for the multi-objective economic load dispatch problem with emission constraints. The results obtained by the algorithm were efficient and effective over stochastic nature algorithms. Xin she Yang et.al.[4], presented the novel approach for solving the economic load dispatch problem using the firefly algorithm with non-linear behaviour of the power system. Later on so many other researchers used the same method with the addition of certain characteristics and constraints of the power system to find the optimal scheduling of the generation so as to optimize the cost. Christober and Asir Rajan proposed a new approach for solving the short term unit commitment problem with Evolutionary Programming Based Simulated Annealing Method considering cooling and banking constraints. The main aim of this method was to reduce the overall cost of generation by proper generation scheduling [5]. Christober Asir Ranjan et al.[6] presented a new Neural Based Tabu Search algorithm for solving the unit commitment problem. The main objective of this paper was to minimize the total operating cost of generation by providing the proper scheduling of the generating units subjected to various constraints. Mimoun Younes [7] proposed a hybrid Firefly Algorithm where they include the renewable energy as a source of primary fuel so as have least possible emission of pollutants.

3. INVESTIGATION

3.1 Economic Load Dispatch

Economic load dispatch is the process of allocating the number of generating facilities among different units to meet the load requirements considering the transmission and operational constraints in such a way that the overall generation cost is minimized. For an optimum operation, the generators with the lowest marginal costs must be operated first. If the total demand on a certain power plant be P_D and the number of generating units be say "n. To reduce the total overall cost of generation, the generating units needs to be operated optimally. This is called as optimization problem. For optimization it is necessary to draw the input output characteristics of every generating unit. Input output characteristics of a certain unit gives us the information about how efficient the given unit is by defining a relationship between input and output. On input side it is the energy used to drive the generator turbine, it maybe heat energy supplied to the generator measured in Btu/hr or kCal/hr. From output side normally it is the electric power generated measured in kW or MW [8].

3.2 Methodologies Used For Optimization Of Economic Load Dispatch And Unit Commitment

Gradient Search Method: It is a first order iterative optimization technique works on the principle of finding the local minima of a differentiable function f(x) by a series of steps. In economic dispatch problem cost function is chosen to be of quadratic form. So as to minimize the cost but it becomes non-linear while considering valve point loading effect.

Newton Method: Newton method provides a better result than simple gradient method, aiming to drive the gradient function to zero. Newton method generally provides a solution for the correction that is much closer to the minimum generation cost than the solution provided by gradient method.

Linear Programming: It is an optimization technique for a linear objective function subjected to linear equalities and linear in-equality constraints. Linear programming will find a point where the given function possess the minimum or max possible value in the optimization surface. Such points may or may not exist, but if they exist, searching through the optimization vertices guarantees to have at least one of them.

Dynamic Programming (DP): Dynamic programming optimization method is mainly used for no-convex cost functions where normal methodologies cannot be applied. In this method of optimization maximization or minimization problem containing n number of decision variables is transformed into n number of individual problems containing single decision variable each in a sequence of Value functions i.e. V_1, $V_2 \ldots V_n$ containing an argument y that defines the state of the system. Calculating the value of the sequence for the respected states of the system gives yields the optimal solution.

3.3 Proposed Approach

Lambda iteration method is the simple algorithm used to solve the economic load dispatch problem where lambda is a variable used for solving constrained optimization problem called as Lagrange multiplier. All the inequality constraints needs to be satisfied in each trial the equations solved by the iteration method. In this method equal increment cost criteria is used for systems without considering transmission losses and the penalty factor matrix for considering losses.

3.4 Analysis of cost function by Lambda Iteration Method

In this test system, value point loading effect, ramp rate constraints, transmission and generation limits are considered. The input data for the 10-unit system is given in Table 1. Also the hourly power demand for 24hrs is given in Table 2. MATLAB program using lambda iteration method has been used for the cost optimization for 24hrs. The result obtained from the lambda optimization technique is given in Table 3, where the optimized cost for the individual unit for each hour is given. As from the table it has been found that the total cost (in Rs/day) obtained by the proposed algorithm is 904513.05. Which is not the lowest value than can be obtained but is quite less than many other algorithms used.

Table 1: Input data of the 10-unit system

Unit	a_1(Rs)	b_1(Rs/MWh)	c_1(Rs/MW^2)	P_{min}(MW)	P_{max}(MW)
U_1	960.2	23.6	0.00063	180	500
U_2	1315.6	23.05	0.00083	165	490
U_3	604.97	22.81	0.00041	103	370
U_4	473.6	25.9	0.0009	90	330
U_5	482.29	23.62	0.00081	103	273
U_6	603.75	19.87	0.00076	83	190
U_7	504.7	18.51	0.00231	50	160
U_8	641.4	25.23	0.005	77	150
U_9	457.6	21.58	0.1108	50	110
U_{10}	694.4	24.54	0.00971	85	85

Table 2: Hourly demand for a day period

Hour	Demand	Hour	Demand
1	1066	13	2102
2	1140	14	1954
3	1288	15	1806
4	1436	16	1584
5	1510	17	1508
6	1658	18	1658
7	1732	19	1806
8	1806	20	2106
9	1954	21	1954
10	2102	22	1658
11	2176	23	1362
12	2250	24	1204

3.5 Results And Conclusion

In this paper we are have discussed various techniques by which economic load dispatch problem can be solved. Also the economic load dispatch problem has been solved by using lambda iteration method for 24 hour power demand to obtain the optimum cost of generation units. As from the results obtained the cost of generation is being optimized to have least possible cost which is not least but is less than the cost obtained by using many other optimization techniques. The results in the Table 3 clearly shows the best fuel cost for the 24 hours i.e 904513.05 Rs as per the input data provided in Table 1 and also in the same Table 3, the fuel cost for individual units is listed with their respective lambda value.

Table 3: Optimized cost of generation for 24 hours

Hour	Load Demand (MW)	Lambda (Rs/MWh)	Fuel cost (Rs)
1	1066	23.12	22954.646411
2	1140	23.14	24666.417081
3	1288	23.17	28093.367593
4	1436	23.20	31524.863671
5	1510	23.22	33242.316296
6	1658	23.25	36680.630721
7	1732	23.26	38401.492520
8	1806	23.28	401230.490711
9	1954	23.31	43570.896265
10	2102	23.34	47022.847385
11	2176	23.35	48750.527532
12	2250	23.37	50479.344069
13	2102	23.34	47022.847385
14	1954	23.31	43570.896265
15	1806	23.28	40123.490711
16	1584	23.23	34960.905313
17	1508	23.22	33195.883716
18	1658	23.25	36680.630721
19	1806	23.28	40123.490711
20	2106	23.34	47116.206448
21	1954	23.31	43570.896265
22	1658	23.25	36680.630721
23	1362	23.19	29808.547436
24	1204	23.15	26147.783807
Total cost (Rs/day)			904513.05

4. CONCLUSION

The main aim of the power system reserve is to maintain the power balance between generation and the demand. Maintenance reserve is the amount of power which is used to balance the generation during any equipment maintenance scheduling in the power system. Operating reserve is mainly used during any equipment failure and the load forecasting error to maintain the equilibrium between the generation and the demand. That's why operating reserve is subdivided into emergency reserve and the load reserve. Emergency reserve is generally used to compensate the power loss while maintaining the load at emergency and during sudden shutdowns of the units in the power plants.

Spinning reserve is that generation capacity that is online but not loaded and can respond very fast so as to compensate for generation or transmission outages. Frequency responsive spinning reserve respond within max of seconds to balance the system frequency which may get deviated during any outages. In general the generating units must have a few percentage of immediate reserve capacity that can be made possible only if the generating units are operated below their rated capacity, extra fuel is used or water is wasted in case of hydro power plant. Thus increasing the total generation cost and the CO_2 emission. Therefore it is necessary to have the optimal scheduling of the spinning reserve for the power system which can be made possible only by optimum unit commitment and economic load dispatch. In this paper we have mainly focussed on the economic load dispatch which plays an important role in maintaining the reserve capacity requirements within the system in an economical manner.

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