International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Unit Commitment by an Improved Priority List Method

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Abstract: ***Unit commitment problem helps in deciding which generation unit should be running in each period so as to satisfy a predictably varying demand for electricity. Unit Commitment enables uninterruptible power to be delivered to consumers using the principle of minimum operating cost. In this work, the unit commitment problem is solved using improved priority list method approach. The generators are switched ON and OFF on a priority basis to minimize the total operating cost of the generating units. The numerical results show that the improved priority list can commit the most economic unit first much better than other existing PL methods.***

Keywords: improved priority list method, unit commitment, priority list

1. Introduction

The demand and supply of electricity need to be in constant balance. As demand for electricity has a typical weekly and seasonal pattern, power plants need to be carefully scheduled to meet this fluctuating demand. This scheduling optimization is known as the unit commitment (UC) problem and has been widely discussed in the literature [1]. Traditionally, the UC problem was solved centrally, minimizing overall system cost. With the liberalization of electricity markets worldwide, the aim is to operate the electricity generation systems with higher (economic) efficiency [2]. Focus has shifted to optimal economic performance and profit maximization. On the one hand, the UC problem can be considered from a system's perspective, i.e., the so-called security-constrained UC. This type of UC is similar to the traditional UC and is what an Independent System Operator (ISO) currently deals with. Also towards policy making and planning, this UC is useful as a tool to perform market simulations and assess the impact of specific measures. On the other hand, from the viewpoint of a single market player, a price-based UC problem can be considered, optimizing output towards maximum profit, based on electricity price forecasts [3, 4, 5].A wide range of solution techniques for the UC problem have been proposed and developed over the years. Examples include priority listing (heuristics), Lagrangian relaxation, dynamic programming, genetic algorithms, etc., together with hybrid methods combining several of these. Hence, the aim of this work is to set up an adequate UC optimization tool that is able to cope with variable and low net demand profiles in an efficient way. Such model is relevant for several market parties, all with their specific objectives. It is further usable for energy and climate policy evaluation and assessment. Also electricity generating companies can use this kind of model, e.g., to provide operational solutions on relatively large sale, or use the model in combination with other techniques such as MILP, to provide a starting solution. Towards this end, a new improved priority list (IPL) based method will be developed. Several priority list methods have been developed in the literature. The Unit Commitment (UC) is an important research challenge and vital optimization task in the daily operational planning of modern power systems due to its combinatorial nature. Because the total load of the power system varies throughout the day and reaches a different peak value from one day to another, the electric utility has to decide in advance which generators to start up and when to connect them to the network and the sequence in which the operating units should be shut down and for how long. The computational procedure for making such decisions is called unit commitment. Unit commitment plans for the best set of units to be available to supply the predict forecast load of the system over a future time period [9].

2. Unit Commitment

2.1 Problem formulation

In this section, we first formulate the UC problem. The objective of the UC problem is the minimization of the total production costs over the scheduling horizon. Therefore, the objective function is expressed as the sum of fuel and start-up costs of the generating units

The objective function of UC to be minimized is

$$\text{Total cost} = F_i(P_{i,t}) + C_{i,t}$$

Where:

$F_i(P_{i,t}) = a_i + b_i(P_{i,t}) + c_i(P_{i,t})^2$

The constraints include

(a) Limits of generation:

The produced power of each unit must obey the minimum and maximum capacities, which can be defined as:

$$P_{imin} \le P_{i,t} \le P_{imax}$$

(b) Power-demand balance:

The power produced by all committed units must meet the system load demand, which is formulated as :

$$\sum_{(i=1,N)} P_{i,t} - P_D = 0$$

(c) Requirements of reserve: To maintain system reliability, adequate reserve requirement must be met at each period, which is represented as:

$$P_{max} \geq P_{i,t} + P_D$$

(d) Limits of minimum up/down:

$$T_{(i,on)} \leq X_{(i,on)}$$
$$T_{(i,off)} \leq X_{(i,off)}$$

Where:

$F_i(P_{i,t})$ = production cost function;

$C_{i,t}$ = startup cost;

a_i, b_i, c_i = coefficients of the quadratic production cost of unit i;

$T_{(i,on)}$ = minimum up time of unit i;

$T_{(i,off)}$ = minimum down time of unit i;

$X_{(i,on)}$ = duration during which unit i is continuously online;

$X_{(i,off)}$ = duration during which unit i is continuously offline;

2.2 Data specification

Table1: Generator system operator data

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
Pmax (MW)	455	455	130	130	162
Pmin (MW)	150	150	20	20	25
a($/h)	1000	970	700	680	450
b($/MWh)	16.19	17.26	16.60	16.50	19.70
c($/MWh2)	0.00048	0.00031	0.002	0.00211	0 .00398
Min Up (h)	8	8	5	5	6
Min Down (h)	8	8	5	5	6
Hot start cost ($)	4500	5000	550	560	900
Cold start cost ($)	9000	10000	1100	1120	1800
Cold start hrs (h)	5	5	4	4	4
Initial status (h)	+8	+8	-5	-5	-6
	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
Pmax (MW)	80	85	55	55	55
Pmin (MW)	20	25	10	10	10
α ($/h)	370	480	660	665	670
β ($/MWh)	22.26	27.74	25.92	27.27	27.79
γ ($/MWh2)	0.00712	0.0079	0.00413	0.00222	0.00173
Min Up (h)	3	3	1	1	1
Min Down (h)	3	3	1	1	1
Hot start cost ($)	170	260	30	30	30
Cold start cost ($)	340	520	60	60	60
Cold start hrs (h)	2	2	0	0	0
Initial status (h)	-3	-3	-1	-1	-1

A system comprising of 10 generators is adopted as the test bed in this work. The data specifications are given in Table1 with the demand over 24-hour period available in Table2.

Table 2: Demand for 24 hours

Hour	DH	Hour	DH
1	700	13	1400
2	750	14	1300
3	850	15	1200
4	950	16	1050
5	1000	17	1000
6	1100	18	1100
7	1150	19	1200
8	1200	20	1400
9	1300	21	1300
10	1400	22	1100
11	1450	23	900
12	1500	24	800

3. Priority List Method

The goal of the PL is to commit the most economic unit first to satisfy the constraints of the UC problem. The PL is often used to solve UC neglecting the ramp rate constraints, thus, only if the on/off status of a solution satisfies the spinning reserve constraints and the minimum up/down time constraints, this method is feasible for UC without ramp rate constraints [10]

4. Improved Priority List Method

The PL is easy to implement and has fast convergence rate. Nevertheless, it usually suffers from the highly heuristic property and relatively poor quality solutions. The reason for the poor solutions is that the PL neglects the minimum up/down time constraints when committing units to satisfy the spinning reserve constraints. To make the initial solution meet the minimum up/down time constraints, a series of heuristics are used to commit some new units order-commit some on-line units, which is likely to violate the principle committing the most economic unit first since some costly units may be committed or some cheap units may be de-committed to meet the minimum up/down time constraints. As a result, the quality of the solutions obtained by PL is not too high. To overcome these problems an advanced priority list method is used.To improve the solution we now investigate the solution without considering the MU and MD constraints when turning on the generator based on the priority order. The MU and MD constraints are considered in calculation of startup cost to avoid the cold start cost when a generator is turned off for more than the summation of MD and cold start hour. The following are the core procedures in MPL:

1) Turn on the generator in the order of priority
2) Check the MD from 1st to 24th hour in the order or priority of the generators. If the generator is off between two on states and the off duration is less than the MD, turn on the generator at those hours. To compensate the extra generated power, consider turning off generator from the most expensive one if this does not violate the spinning reserve, MU and MD constraints.
3) Check MU from 1st to 24th hour in the order of priority of the generators. Turn on the generator for the next hour until MU is satisfied. Once again, to compensate the extra
4) generated power, consider turning off generator from the most expensive one if this does not violate the spinning reserve, MU and MD constraints.

5. Methodology

a) Create a PL on the basis of Pmax value .if the value Pmax of two units are same then check the heat rate of two units and the unit with minimum value comes first in the priority list.
b) Use the PL to commit units until the load demand plus the spinning reserve are fulfilled at each period. Denote the on/off status as an initial solution for UC without ramp rate constraints. The total capacity of the committed generating units must be bigger than or equal to the load and the specified spinning reserve.

c) Perform some heuristics to repair the initial solution to meet the minimum up/down time constraints at period inserted into the load peak.
d) Perform some to repair the solution obtained in Step 2 to meet minimum up/down time constraints of all periods.
e) Calculate the production costs by economic load dispatch (ELD) and startup costs by applying some heuristics. Add the both costs to get the total operation costs.

6. Results

Table3: Solutions for improved priority list method

Time in hours	*Production cost*	*Startup cost*
1	13683	0
2	14554	0
3	16809	900
4	18589	0
5	20020	560
6	22387	1100
7	23262	0
8	24150	0
9	27251	860
10	30058	60
11	31916	60
12	33890	60
13	30058	0
14	27251	0
15	24150	0
16	21514	0
17	20642	0
18	22387	0
19	24150	0
20	30058	490
21	27251	0
22	22736	0
23	17684	0
24	15427	0
total cost	**559887**	**4090**

7. Conclusion

The improved priority list is simple and more efficient than conventional priority list method. All the associated constraints are met in the results.The Economic Dispatch (ED) is solved using the lambda iteration method. The simplicity of the improved priority list and fast calculation of ED leads to a methodological and competent method in comparison with conventional method. After calculation it is concluded that the consideration of minimum up and down constraints are necessary to minimize the overall cost.

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