Unit Commitment

Introduction - With the development of large integrated power systems i.e. interconnecting a no. of power plants in parallel to supply the system load, it becomes necessary to operate the plant units most economically. For this economic scheduling of generators is required to guarantee that at all times there is an optimum combination of generators connected to the system to supply the load demand. The unit commitment ~~problem deals with the~~ is a term used for strategic choice to be made in order to determine which of the available power plants should be considered to supply electricity. The main factor which controls the most desirable load allocation between various generating units is the total running cost.

Unit Commitment - Unit commitment further abbreviated as UC, refers to the strategic choice to be made in order to determine which of the available power plants should be considered to supply electricity. The electrical unit commitment problem is the problem of deciding that for a given load profile, a given set of units (generation units) available when should each unit be started stopped and how much should it generate to meet the load at minimum cost. The obvious policy is that as demand increases, we just turn on the efficient but costly to start generator and lastly turn on the least efficient but cheap to start. As demand decreases, we shut down the units in reverse order.

<u>Economic Load Dispatch</u> – It means optimum generation scheduling of available generators in an interconnected power system to minimise the cost of generation subject to relevant system constraints. ELD is an important function in power system and operation.

<u>Difference between UC and ELD</u> – UC (unit commitment) is not the same as ELD (economic load dispatch). UC means for a given load and given set of units available, a strategic choice is to be made as to when should each unit be started, stopped and how much should it generate to meet the load at minimum cost.

ELD means for a given load and a given set of units online, how much should each unit generate to meet this load at min. cost. ELD consists of fitting a given set of power plants into a certain electric demand. UC appoints the set of plants from which dispatching can be chosen. The difference between UC and ELD is of time.

In taking ELD decisions, there is no time to rapidly activate a power plant because inertia of most plants will not allow this.

UC therefore prepares a set of plants and stipulates in which time period they have to be online and ready for dispatching. UC chooses plants taking into account a wide variety of parameters, techonological aspects as well as economical considerations (such as start-up costs and operational costs) and social elements (such as availability of staff and work schemes). UC optimization enables power generation utilities to minimize electricity generation costs.

Unit Commitment Planning – The electrical unit commitment problem is the problem of deciding which electricity generation units should be running in each period so as to satisfy a predictably varying demand for electricity. In a typical electrical system there are a variety of units available for generating electricity, and each has it's own characteristics. At one extreme end is a nuclear power unit which can provide electricity at a very low incremental cost for each additional MWh of energy but it has a high cost of starting up again once it has been shut down and it takes a while to bring it back up to full power. At the other extreme end, a gas turbine generator can be started up in a few minutes. However it's incremental cost per MWh is much more expensive.

There are several optimisation techniques based on classical, linear programming, nonlinear programming and quadratic programming have been used in the past for solving the ELD problem. Among these techniques, the classical technique based on co-ordination equations has proved to be simplest and fastest, but suffers from an inability to handle the constraints effectively and hence has limited application. The classical technique requires the solution of a set of co-ordination equations wherein penalty factors are computed using transmission loss formulation through B coefficients, general transmission loss formulation or generation of loss coefficients.

Economic Load Dispatch (ELD) – The factors which influence the generation of power at min. cost are operating efficiencies of generators, fuel cost and transmission losses. It may happen that the most efficient generator in the system does not give min. cost as it maybe located so far from the load centre that the transmission losses maybe considerable high thereby making the plant uneconomical. In economic load dispatch, the problem is to determine the generation of different plants such that the operating cost is minimum.

Ex. Given

Unit 1 — $P_{min} = 250MW$, $P_{max} = 600MW$

$C_1 = 510.0 + 7.9P_1 + 0.00172P_1^2$ Rs/hr

Unit 2 — $P_{min} = 200MW$, $P_{max} = 400MW$

$C_2 = 310.0 + 7.85P_2 + 0.00194P_2^2$ Rs/hr

Unit 3 — $P_{min} = 150MW$, $P_{max} = 500MW$

$C_3 = 78.0 + 9.56P_3 + 0.00694P_3^2$ Rs/hr

What combination of units 1, 2 and 3 will produce 550 MW at min. cost? How much should each unit in that combination generate?

Sol. Let $P_1 = 400MW$, $P_2 = 150$ MW

Therefore

$C_1 = 510.0 + 7.9 \times 400 + 0.00172(400)^2$

$= 3945.2$ Rs/hr

$C_2 = 310.0 + 7.85 \times 150 + 0.00194(150)^2$

$= 1531.15$

$C_{total} = C_1 + C_2$

$=$ Rs/hr 5476.35

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The following table shows the cost of the various combinations for power generation:-

Unit 1	Unit 2	Unit 3	P_{min}	P_{max}	P_1	P_2	P_3	C_{total}
off	off	off	0	0	Infeasible			
off	off	On	150	500	Infeasible			
off	On	off	200	400	Infeasible			
off	On	On	350	900	0	400	150	5428.55
On	off	off	250	600	550	0	0	~~5389~~ 5325.3
On	off	On	400	1100	400	0	150	5613.35
On	On	off	450	1000	295	255	0	~~5471~~ 5428.05
On	On	On	600	1500	Infeasible			~~5617~~

The following observations can be deduced from the above table

* far too few units committed can't meet the demand
* if enough units are not committed then some units operate above optimum
* if too many units are committed then some units will operate below optimum
* if far too many units are committed then min. generation exceeds demand

Constraints in Unit Commitment – In the case of unit commitment many constraints can be placed ~~the constraints~~ ~~which are placed~~ which can be classified into the following two categories:-

A.) Unit Constraints
B.) System Constraints

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M		10	24
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W		12	26
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S	02	16	30
M	03	17	31
T	04	18	
W	05	19	
T	06	20	
F	07	21	
S	08	22	

A) Unit Constraints – These ~~constraints that~~ are those constraints that affect each unit individually. The unit constraints are as follows:-
(i) max. generating capacity
(ii) min. stable generation
(iii) flexibility
(iv) min. up time
(v) min. down time
(vi) ramp rate

(1) Max. Generating Capacity – In the case of unit commitment while allocating load to each unit, it's generating capacity has to be taken into account since a unit cannot be loaded beyond it's max. generating capacity.

(2) Min. Stable ~~Operation~~ Generation – In the case of power plants, the min. amount of power to be generated is not zero because for the stable operation of the boiler a min. amount of power needs to generated by the generating unit. Hence in unit commitment the min. amount of power to be generated for stable operation of boiler is to be considered while allocating the load between various generating units.

3) Flexibility – In the case of unit commitment while allocating the load among various generating units, the flexibility of the plant has to be taken into account. All the plants can be classified into the following two types:

(a) Flexible Plants
(b) Inflexible Plants

Flexible plants are those plants whose power output can be adjusted within limits. e.g. thermal units (coal fired, oil fired, open cycle gas turbines, combined cycle gas turbines) and hydro plants with storage. In the case of these plants both the status and the power output can be optimised

Inflexible plants are those plants whose power output cannot be adjusted for technical or commercial reasons. e.g. nuclear plants, run of the river hydro, renewables (wind, solar etc.) and combined heat and power units (CHP, cogeneration). In the case of these plants the output is treated as given when optimising

4.) Minimum Up time – Once a unit is running it may not be shut down immediately. The minimum time required for a unit to shut down properly is known minimum up time.

If $X_i(t) = 1$ and $t_i^{up} < t_i^{up,min}$
then $X_i(t+1) = 1$

where

$X_i(t) \rightarrow$ state of ith unit at time t

$t_i^{up} \rightarrow$ up time of ith unit

5.) <u>Minimum Down Time</u> - Once a unit is shut down, it may not be started immediately. The ~~time~~ min. time required for a unit to become operational from shut down condition is known as minimum down time

If $X_i(t) = 0$ and $t_i^{down} < t_i^{down,min}$

then $X_i(t+1) = 0$

where

$X_i(t) \longrightarrow$ state of ith unit at time t

$t_i^{down} \longrightarrow$ down time of ith unit

6.) <u>Ramp Rate</u> - It is the rate of change of electrical power output from a power plant. In order to avoid damage to the turbine, the electrical output of a unit cannot change by more than a certain amount over a period of time

max. ramp up rate constraint is

$$P_i(t+1) - P_i(t) \leq \Delta P_i^{up,max}$$

max. ramp down rate constraint is

$$P_i(t) - P_i(t+1) \leq \Delta P_i^{down,max}$$

where $P_i(t) \rightarrow$ electrical output of ith unit at time t

$P_i(t+1) \rightarrow$ electrical output of ith after time t+1

$\Delta P_i \rightarrow$ change in electrical power output of i th unit.

B) System Constraints — These are the constraints that affect more than one unit. The types of system constraints are as follows:

(i) Load/generation balance
(ii) reserve generation capacity
(iii) crew constraints
(iv) emission constraints
(v) network constraints
(vi) inequality constraints

~~(i) Load/Generation Balance~~ —

(i) Load/Generation Balance — It is also known as equality constraint. Now as per this constraint in a unit commitment problem, the total amount of electrical power being generated by the committed units should be equal to the total load demand.

$$\sum_{i \in C(t)} P_i(t) = L(t)$$

where $C(t) = \{ i \mid X_i(t) = 1 \}$: set of units committed at time t

$P_i(t)$ = power output of unit i at time t

(ii) <u>Reserve Generation Capacity</u> — These constraints are required to meet unanticipated loss of a generating unit or an interconnection because it causes unacceptable frequency drop if not corrected. In order to keep the frequency drop within acceptable limits there is a need to increase production from other units, ~~to keep frequency~~ The rapid increase in production is possible only if ~~all~~ some of units committed are not operating at their max. capacity.

Now a question arises as to how much reserve should be provided to protect the system against credible outages. Two types of criteria are generally applied for determining the amount of reserve capacity required

a) <u>Deterministic Criteria</u> — In this case for determining the reserve capacity, the capacity of largest unit or interconnection as well as percentage of peak load is taken into account

b) <u>Probabilistic Criteria</u> — In this case for determining the reserve capacity, the number and size of the committed units as well as their outage rate is taken into account.

<u>Types of Reserve</u> — The reserve which are put into use are of the following types:-

(i) spinning reserve
(ii) Scheduled or off-line reserve
(iii) other sources of reserve