Chapter 6

Unit Commitment

6.1 Introduction

In power systems, demand variation is associated with human activities. Load is always light during night hours and it starts increasing right from morning and usualy reaches its peak lavel in the evening, and again falls during late evening period. The demand is also affected during week ends as well as by weather. Hence, many methods have been developed for load forecasting. The methods for load forecasting can predict the load for period varying from as small as few seconds to days. Based on these load forecasts, the usual practice is to prepare a commitment schedule of start-up and shut-down of units. The commission of a generating unit means to bring it to speed, synchronize it to the system and then connect it to the system so that it can deliver the load reliably. Since the inception of power generation, importance of unit commitment was realized and many researchers have attempted to solve the problem efficiently. Initially, power generation was done using coal, hence main thrust of research was only on thermal system and even today researchers are developing various techniques for thermal system. In the early stages, the main criteria of unit commitment was efficiency of units. Units used to be ordered as per efficiencies. The most efficient unit used to be committed first and then the next unit, if necessary to meet the load demand, from priority list used to be committed. Soon, it was realized that optimum unit commitment may be obtained using input-output characteristics, termed as cost curves; and today all commitment techniques are based on these cost curves. Classically, unit commitment is the determination of optimal schedule and generation level of each unit over a specific time horizon. Time horizon may be hours or a week. So far, many researchers have contributed to this aspect and different mathematical techniques have been used to find the optimal solution. Baldwin [61] was the first to report the study of economic shut down of generating units. Since then, many optimization techniques have been used to obtain solution of unit commitment problem; prominent among these are dynamic programming, branch and bound, Lagrangian relaxation [8, 127]. Very few researchers have included energy sources such as hydro and gas

[62, 82, 87, 104] along with coal, for unit commitment. Now a days, due to awareness of pollution caused by thermal plants and consequently their effects on ecology, various countries have made it mandatory to include control of emission while generating power. Hence, unit commitment programs include pollution control. After going through the literature on research related to use of dynamic programming for unit commitment, the main drawback is found to be the need for large computer memory due to large number of units. Various states which are to be preserved at various stages and required to be checked for minimum operating cost, start-up and shut-down costs, class of units such as must-run unit, peaking unit, schedulable unit as well as their minimum up and down times make the problem more complex. Moreover, complexity further enhances due to environmental constraints. Some researchers have included NOx and/or SOx constraints in unit commitment. Recently, Sen and Kothari [126] have presented comparison of unit commitment schedules incorporating emission. In these works, emission is mainly controlled over an area. In reality, plants are sparsely located and environmental condition may differ from plant to plant , and hence, it becomes necessary to include local emission constraints in unit commitment.

Having established in previous Chapters, various aspects such as scheduling by dynamic programming, scheduling of mix system, economic and environmental dispatch and merit ordering of units, the aim of work in this Chapter is to develop unit commitment methodology for mix generation system, mainly consisting of thermal, hydro and gas plants, taking into account emission of NOx as one of the main constraints.

This work takes into account emission constraint at each site where the various units of a power plant are located. Units such as hydro and gas are classed as must-run units. Hydro units included for unit commitment are assumed to have fixed head during commitment period with specified amount of water to be utilized. Gas units considered are of *take* or *pay* type. Inclusion of these units pose no problem because of quadratic nature of their consumption functions which can be converted into cost function by applying weighting factors. The procedure begins with the assumption that merit order of units are available at every plant and units are available accordingly for unit commitment for next twenty four hours period.

6.2 Unit Commitment Strategy

As compared with conventional approach practiced by utilities, our unit commitment approach is different in the sense that units are grouped plantwise and unit commitment is performed on the basis of priority ordering and sequential combination, as developed in Chapter 3. Moreover, in Chapter 4, economic dispatch of mix system is reported and in Chapter 5, environment and economic dispatch is developed in which it is shown that the maximum limit of generation can be obtained with due consideration for NOx constraint. This limit is naturally less than the capacity of unit. Due to this limit some generation has to be shifted from high emission plant to low emission plant so as to satisfy emission constraint. In this Chapter, overall unit commitment is attempted considering all the above aspects, with following assumptions.

- Unit commitment is planned for 24 hours.
- Demand set is deterministic and unit commitment horizon is subdivided in 24 hours with each subdivision of one hour duration.
- All units are available for unit commitment and can be synchronised as and when required.
- Patton's security function is considered for assessment of security.
- Every plant is assigned maximum NOx level.
- Hydro and/or gas plants are available throughout the commitment period.

It is proposed to obtain optimal solution for the following two systems.

- Thermal system only
- Mix system

For both the systems, two types of problems are attempted.

- Priority ordering is first completed and then unit commitment is performed, followed by dispatch.
- Priority ordering is first completed incorporating emission constraint and then unit commitment is performed, followed by dispatch with emission constraint.

6.3 Unit Commitment Thermal system

While performing Unit Commitment (UC), merit ordering or priority order of units is first obtained at each plant and then unit commitment procedure is initiated. The procedure developed is very simple and easy to be implemented.

6.3.1 Problem Formulation

Conventionally, the problem is formulated as

$$F_T = Min[\sum_{t=1}^{24} F_t(D_t)] \tag{6.1}$$

$$Min[F_t(D_t)] = Min[\sum_{i=1}^{N_p} \sum_{j=1}^{m_i} F_{ij}(p_{ij})] \tag{6.2}$$

subject to

$$D_t = \sum_{i=1}^{N_p} \sum_{j=1}^{m_i} p_{ij} \tag{6.3}$$
$$p_{min_{ij}} \leq p_{ij} \leq p_{max_{ij}}$$
$$P_{min_i} \leq DP_i \leq P_{max_i}$$
$$NOx_i \leq NOxd_i$$
$$S(t)_i \leq MTIL_i$$

where
D_t is the system demand at time t,
$p_{min_{ij}}$ is minimum generation limit on unit j of plant i,
$p_{max_{ij}}$ is maximum generation limit on unit j at Plant i,
P_{min_i} is Minimum generation level at plant i,
P_{max_i} is Maximum generation Level at plant i,
DP_i is generation at plant i,
NOx_i is NOx emission level at plant i,
$NOxd_i$ is assigned NOx level at plant i,
$S(i)$ is security value at plant i,
$MTIL_i$ is Maximum Tolerable Insecurity Level at plant i,
p_{ij} is power generation of unit j at plant i,
F_T is total cost of generation in 24 hours, and
F_t is the cost of generation at time t.

6.3.2 Method Of Solution

As mentioned earlier, the following two strategies are opted:

- To perform UC on economic basis,
- To perform UC on economic and environmental basis and then economic and emission dispatch is performed.

Following the assumptions mentioned earlier and a set of demand, UC is initiated at mid night and terminated after 24 hours. Before the selection of units at various plants, merit ordering is performed at each plant.

6.3.2.1 Unit Commitment Schedule of Thermal System

After having obtained priority Table at each plant, it is easy to obtain UC of the entire system. However, selection of the units at various plant is tedious in the sense that for the given demand, units at plant level are selected just by searching the range and corresponding combination. However, the same is not easy for multi plant system. For this purpose two methods can be applied. At first hour of the day, plantwise generation is calculated just by distributing the demand equally and then units are selected at each plant, as per plant load so calculated. In the next step, optimum combination selection is attempted iteratively by running economic dispatch algorithm. This method may be applicable for small capacity plants, but the same cannot be used for large plants due to the fact that there may be large gap between maximum capacity of plants in the system. Hence, initial distribution of load at plants is obtained using [25] capacity distribution method, that is,

$$P_i = \frac{D}{\sum P_{max_i}} * P_{max_i} \tag{6.4}$$

In this expression, capacity of individual plant is taken into account. Hence, while performing UC, second strategy is adopted. Using plant generation from equation (6.3), units are selected at each plant by searching for appropriate range of operation. However, the selection is not optimum. This is because, with these selected units, recalculated plant load may not match the range of operation so selected. Hence, after selecting the units coarsely, economic dispatch is performed; plant load is calculated; and the units are selected accordingly. However, due to difference in plant characteristics, selection may not be obtained in one stroke but may require more iterations. The iterative procedure is repeated until there is no appreciable change in the cost of generation over two successive iterations. While performing dispatch, care has to be taken to include constraint on individual unit capacity as well as plant capacity. On violation of unit constraint, plant cost function is required to be corrected. Therefore, in optimum selection loop , this constraint is also included. Adopting the above technique, unit selection is completed for first hour load. For the next hour, either the same methodology may be repeated or on the basis of first strategy, selection of units is processed. Either way, results obtained would be the same and so first methodology is adopted. The procedure is repeated for 24 hours and plantwise unit commitment Table is formed. Advantage of this method is that regardless of the number of units (grouped plantwise), there is no difficulty in obtaining unit commitment of the system, which otherwise is a difficult task. The entire procedure as discussed above can be summarized by the following algorithm.

(1) Form merit order, order of combination and range of operation at all plants.

(2) At first hour of UC horizon, select demand of the hour.

(3) Using equation (6.3), find temporarily generations at all plants, set iteration count to 1

(4) Using the plant generation, select the units by searching appropriate range of operation and form plant cost function at all plants.

(5) Using plants' cost functions, calculate generations at all plants.

(6) Using the plants' generations, check again the units or unit combinations at all plants. If units are changed, form cost functions again.

(7) Having calculated the plant load, calculate individual unit generation taking inequality constraint into account. On violation of unit limits, correct plant equivalent cost functions.

(8) Calculate cost of generation and check the same with that of previous iteration. If no change is observed, go to step 9; otherwise, repeat from step 5.

(9) Repeat the procedure for all demands of the day and finally obtain the UC Table. This Table provides hourly information on demandwise units and their combination.

6.3.2.2 Emission Constrained Unit Commitment of Thermal System

The aim of this subsection is to develop a methodology to select the units at plant on the basis of economic as well as emission constraints. This is achieved by executing first the merit ordering procedure at every plant. Then, every combination order and its range of operation is checked against NOx limit. The combination order starts from first unit and NOx violation by few units is a rare possibility. Hence, checking of NOx violation can be started from combination order having at least 50% of the total units of the plant. Every upper range of operation is taken as demand on plant and dispatch calculation is performed to minimize NOx. If Minimized NOx is equal to or less than NOx constraint, no action is required. On violation of the constraint, upper range is reduced step by step till NOx is less than desired NOx level, and then by interpolation, the range is estimated at which minimized NOx is equal to or nearly equal to the specified NOx. The procedure is repeated till last combination and its range are covered. By adopting above procedure, units are selected on economic basis and their range of operation is decided by NOx level. In this way, merit order of units are prepared at every plant taking NOx constraint into account. Then the unit commitment and dispatch procedure is the same as discussed in previous section 6.3.2.1. Having completed optimum selection of units plantwise, UC Table is prepared. The next step is to confirm the status of units at every plant taking into account security or sufficiency of units with due regard to individual outage probability or availability. For this purpose, Patton's security [5] function is adopted at each hour. The Patton's security function thus calculated is compared with MTIL at the plant. The MTIL selection is a matter of management. If combination of units provides higher value than MTIL, the next economic unit is added in the set of units. This procedure is repeated till a set of units provide security level less than or equal to MTIL. The same procedure is repeated on all plants. Next task is to calculate dispatch for 24 hours taking into account NOx emission constraint. To include NOx constraint same strategy as discussed in Chapter 5 is adopted. At every hour at each plant, NOx level is calculated for estimated load. Now, the NOx may or may not be within limits. Therefore, the following steps have to be followed, to include NOx constraint.

(1) If plant is within NOx limit, no action is required to be taken.

(2) On occurrence of violation of NOx level for a particular load, NOx level is minimized and unit generation is recalculated.

The minimized NOx may exhibit three possibilities as follows

- Minimum NOx calculated may be higher than the specified level.
- Minimum NOx calculated may be equal to specified level.
- minimum NOx calculated may be less than specified level.

In case of first possibility, maximum capacity of the plant is reestimated so that at current load, minimized NOx is equal to specified NOx. The method of estimation of plant capacity is as described above. In case of second possibility no action is required to be taken. And in case of third possibility, tradeoff is required. This is because the minimization of NOx always causes higher cost of generation. Therefore, tradeoff is adopted so as to obtain minimum cost along with NOx constraint, that is, generation of every unit at a plant is adjusted to maintain emission level at specified value at minimum cost. All the above three possibilities are checked while estimating unit commitment schedules. The entire procedure can be condensed in the form of an algorithm, as follows.

(1) Correct order of combinations at each plant based on emission constraint.

(2) Repeat the procedure from step 1 to 9 as in previous section.

(3) Correct the combination of units plantwise for each hour using security criteria.

(4) On finalizing the units at every plant, form plants' equivalent functions. Set iteration count to 1.

(5) Using plant cost functions, find generation of the plant.

(6) Using plant generation, estimate individual unit generation and check for inequality constraint. If this is violated, correct plant functions.

(7) Calculate total cost of generation and compare cost at previous iteration. If no change in cost occurs, go to next step; otherwise, repeat from step 6.

(8) Check unit allocation at every plant for specified NOx. On violation of NOx constraint, find generation scheduling by minimizing NOx. If minimized NOx is less than the specified, execute tradeoff program and estimate new generation of each unit.

(9) Repeat the procedure for all loads of the day and finally calculate total cost.

6.4 Unit Commitment of Mix-generation System

Very few researchers have reported unit commitment incorporating non-thermal plant such as hydro and gas. Incorporation of these plants has now become a simple task, due to procedure adopted in previous section. The procedure for UC of mix-system is worked out considering the two cases as follows.

- UC of mix-system and economic dispatch.
- NOx constrained UC and economic and environment dispatch.

Because only constraints are incorporated in both cases, the basic idea for obtaining the UC, is the same as developed for UC of thermal system. Additional loop is required to incorporate non-thermal subsystems in mix-generation system and the process is to be made iterative to satisfy water and gas constraints of hydro and gas subsystems.

6.4.1 Problem Formulation

Problem formulation is similar to that of thermal system, except that total generation is shared by non-thermal plants and constraints such as total volume of water and gas are included. The total cost of generation is expressed as

$$F_T = Min[\sum_{t=1}^{24} F_t(P_{th})] \tag{6.5}$$

subject to
$D_t = P_{th} + P_h + P_g$,
$Phmin \leq P_h \leq Phmax$,
$Pgmin \leq P_g \leq Pgmax$,
$V_h = V_{sh}$, and
$V_g = V_{sg}$;
where,
D_t is the system demand at time t,
P_{th} is generation from Thermal Plants,
P_h is generation from Hydro Plants,
P_g is generation from Gas Plants,

V_h is total volume of water utilized,
V_{sh} is total specified volume of water,
V_g is total volume of Gas utilized,
V_{sg} is total specified volume of Gas,
$P_{h_{min}}$ is the minimum generation limit of hydro plant,
$P_{h_{max}}$ is the maximum generation limit of hydro plant,
$P_{g_{min}}$ is the minimum generation limit on gas plant, and
$P_{g_{max}}$ is the maximum generation limit on gas plant.
Other constraints such as individual generation limits on thermal plants and units as well as emission and security constraints on thermal plants are same as mentioned in subsection 1.3.1 .

6.4.2 Unit Commitment Schedule of Mix-Generation System

The procedure for UC schedule of Mix-Generation system is a mere extension of the methodology developed in Chapter 3 for mix-generation scheduling. The merit ordering of units as developed in Chapter 4 and used for UC in previous section will be useful here also. For the solution of this problem following assumptions are made.

(1) Both thermal and non-thermal units are available for 24 hours.

(2) Consumption function of non-thermal units are quadratic.

(3) Gas and hydro units are must-run units.

The strategy for solution is naturally iterative and weighting factors converting consumption function into cost function are corrected at the end of iteration by interpolation method. The methodology is summarized in the form of an algorithm as follows:

(1) Complete the merit ordering of units at all thermal plants.

(2) At first hour, the demand is distributed on plants as per their capacity. Using capacity distribution of plants, units on all plants are selected and corresponding equivalent cost functions are formed. Using these cost functions, weighting factors are estimated using equation (3.17) and then all consumption functions are converted into cost functions. The non-thermal system are now treated as similar to thermal system.

(3) Repeat the procedure from step 2 to 9 as per subsection (6.3.2.1).

(4) At the end of commitment horizon, estimate total volume of water or gas and compare the same with target volume and recalculate corresponding weighting factors.

(5) If calculated volumes are sufficiently close to target, stop. Otherwise, repeat the procedure from step 2.

6.4.3 Emission Constrained Unit Commitment and Environment & Economic Dispatch

The last phase of the work is to obtain emission constrained unit commitment and environment and economic dispatch of the mix-system which is now very simple and straight forward. Usefulness of this strategy lies in the fact that both hydro and gas units not only minimize the cost but are also useful to take share of the load when all other plants reach their upper generation limit imposed by NOx constraint. The strategy for this part is now very straight forward and includes steps used in previous section. The procedure can be initiated from step 1 of algorithm stated in previous section and can be continued till step 5. Having obtained UC Table at each plant, mix-generation dispatch program is run taking into account NOx constraint at each plant. The method can now be described by the following algorithm.

- Prepare merit ordering at all plants taking into account NOx constraint.
- Complete UC procedure from first hour to the last hour as developed in previous section.
- Having obtained the UC Table at every plant, correct each Table using security function.
- Once the UC Table is formed, that is, after unit combination at every hour is fixed, the dispatch program of mix system is run again.
- Now, check the unit allocation for specified NOx at every plant. On violation of NOx constraint, find generation scheduling by minimizing NOx. If minimized NOx is less than that specified, execute tradeoff program and estimate new generation of each unit.
- Repeat the procedure for all loads of the day and finally calculate total cost.

6.5 System Studies and Results

As mentioned earlier, it is proposed to obtain optimal solution for two systems:

- Thermal system, and
- Mix system

In both systems, two types of problems are solved:

- Unit commitment and dispatch.
- Emission constrained unit commitment and dispatch.

6.5.1 Unit Commitment and Dispatch of Thermal System

Here, two types of problems are solved - (1) Unit Commitment and Dispatch and (2) Emission Constrained UC and Dispatch. In this problem also, Patton's security function is used to find sufficiency of units.

6.5.1.1 Unit Commitment and Dispatch

A multiplant system with multiple units at each plant is selected. Table 6.1 gives plantwise number of units, Table 6.2 to 6.6 is the input data providing quadratic cost coefficients and bounds on each plant. Table 6.6 is the B-Coefficients. The method developed in Chapter 4 is used to obtain combination order and range of operation at all plants. The results are shown in Tables 6.8 to 6.12. Using this order of combination, unit commitment schedule is obtained for 24 hours period. Tables 6.13 to 6.17 show system demand, plant generation and unit participation (denoted by '1' for commited state and '0' for decommitted states). Table 6.18 gives details of generation of at each plant for some selected demands whereas Table 6.19 gives transmission losses for selected demands.

6.5.1.2 Emission Constrained Unit Commitment and Dispatch

The thermal system used here for emission constrained unit commitment is the same as used in the last section, using the data given in Table 6.2 to 6.6. Tables 6.20 to 6.24 show the emission coefficients of each unit at a plant, whereas Table 6.25 gives the NOx limits at each plant. Order of combination at each of the five plants with NOx constraint is given in Tables 6.26 to 6.30. These Tables show the unit status, upper and lower limits of load on economic basis without and with emission constraint, for five plants. The result of UC program is given in Table 6.31. The Patton's security function is then used at every hour of the day for every plant to evaluate sufficiency or reliability of units at a plant. For selected demands, plantwise unit paticipation is shown in Table 6.32. Dispatch program is then run at every hour of the day. Table 6.33 soows the result of UC schedule. It can be observed from the result that generation of all plants are within NOx constraint.

6.5.2 Unit Commitment of Mix Generation System

For mix generation system, two types of problems are solved. Input data for thermal system is the same as used earlier whereas data for hydro and gas plants is taken from Table 3.19 in Chapter 3.

6.5.2.1 Unit Commitment and Dispatch

Using the same combination order as given in Table 6.8 to 6.12, unit commitment of mix-system is estimated. Table 6.34 shows unit commitment of mix-system. Table 6.35 depicts the unit participation of thermal units of each plant for selected demands.

Table 6.1: Thermal Unit Commitment and Dispatch

plant No.	1	2	3	4	5
units	10	8	6	7	9

Table 6.2: Data for plant No. 1

Unit No.	cost coefficients			bounds	
	a_{ij}	b_{ij}	c_{ij}	$Pmin_{ij}$	$Pmax_{ij}$
1	0.0052	2.103	16.00	18.00	65.00
2	.0039600	1.9161000	25.0000000	20.000	80.00
3	.0039300	1.8518000	40.0000000	30.000	100.000
4	.0038200	1.6966000	32.0000000	25.000	120.000
5	.0021200	1.8015000	29.0000000	50.000	150.000
6	.0026100	1.5354000	72.0000000	75.000	280.000
7	.0028900	1.2643000	49.0000000	120.000	320.000
8	.0014800	1.2136000	82.0000000	125.000	445.000
9	.0012700	1.1954000	105.0000000	250.000	520.000
10	.001350	1.1285000	100.0000000	250.000	550.000

6.5.2.2 Emission Constrained Unit Commitment of Mix-system

The same result as obtained for emission constrained combination order in thermal system is used for this problem. Table 6.36 gives the solution of mix system with emission constraint. Table 6.37 shows unit participation at each plant for selected demands. The same Table is again corrected due to security constraint. Table 6.38 provides the result due to security. Having finally selected units at all hours of the day, dispatch program is run. Table 6.39 shows the result of this program. Table 6.40 to 6.44 give the details of plant and corresponding unit generation for selected demands. Table 6.45 shows the result for selected demands for which some plants violate emission constraints even when their generation is within emission range. This is because the range calculation is obtained by runnig minimum emission dispatch program. Hence, for such plants with the same estimated generation share, tradeoff program is run; and units' generation are adjusted so as to maintain plant at prescribed emission level. It can be seen from Table 6.45 that plants 2 and 3 violate these limits. Table 6.46 & 6.47 show the corrected generation for Demand No.13 and 14 at plant 2; and Table 6.48 & 6.49 present corresponding results for plant 3.

Table 6.3: Data for plant No. 2

Unit No.	cost coefficients			bounds	
	a_{ij}	b_{ij}	c_{ij}	$Pmin_{ij}$	$Pmax_{ij}$
1	.0039600	1.916100	25.0000	20.00	80.0
2	.003930	1.851800	40.0000	30.00	100.000
3	.0021200	1.801500	29.0000	50.00	150.000
4	.0026100	1.535400	72.0000	75.00	280.000
5	.0028900	1.264300	49.0000	120.00	320.000
6	.001480	1.213600	82.0000	125.00	445.000
7	.0012700	1.1954000	105.0000	250.00	520.000
8	.001350	1.128500	100.0000	250.00	550.000

Table 6.4: Data for plant No. 3

Unit No.	cost coefficients			bounds	
	a_{ij}	b_{ij}	c_{ij}	$Pmin_{ij}$	$Pmax_{ij}$
1	.0051000	2.2034	15.000	15.0000	60.000
2	.0038200	1.6966	32.000	25.000	120.000
3	.0026100	1.5354	72.000	75.000	280.000
4	.0014800	1.2136	82.000	125.000	445.000
5	.0012700	1.1954	105.000	250.000	520.000
6	.0013500	1.1285	100.000	250.000	550.000

Table 6.5: Data for plant No. 4

Unit No.	cost coefficients			bounds	
	a_{ij}	b_{ij}	c_{ij}	$Pmin_{ij}$	$Pmax_{ij}$
1	.0039600	1.9161	25.000	20.000	80.000
2	.0038200	1.6966	32.000	25.000	120.000
3	.0021200	1.8015	29.000	50.000	150.000
4	.0026100	1.5354	72.000	75.000	280.000
5	.0028900	1.2643	49.000	120.000	320.000
6	.0014800	1.2136	82.000	125.000	445.000
7	.0013500	1.1285	100.000	250.000	550.000

Table 6.6: Data for plant No. 5

Unit No.	cost coefficients			bounds	
	a_{ij}	b_{ij}	c_{ij}	$Pmin_{ij}$	$Pmax_{ij}$
1	.0051	2.2034	15.00	15.00	60.00
2	.00393	1.8518	40.00	30.00	100.00
3	.00383	1.7966	32.00	25.00	120.00
4	.00212	1.9015	29.00	50.00	150.00
5	.00262	1.6354	72.00	75.00	280.00
6	.00289	1.2643	49.00	120.00	320.00
7	.00158	1.2136	82.00	125.00	445.00
8	.00129	1.1954	105.00	250.00	520.00
9	.00137	1.1285	100.00	250.00	550.00

Table 6.7: Transmission Loss Coefficients

.00003000	.00000420	.00000220	.00000300	.00000700
.00000420	.00004000	.00000620	.00000420	.00000800
.00000220	.00000620	.00005000	.00000650	.00000540
.00000300	.00000420	.00000650	.00004100	.00000660
.00000700	.00000800	.00000540	.00000660	.00005000

Table 6.8: Order of Combination of Plant No. 1

Sr	unit status										Operattion Range		Capacity	
No.	1	2	3	4	5	6	7	8	9	10	Lower Mw	Higher Mw	$\sum Pmin_j$ Mw	$\sum Pmax_j$ Mw
1	0	0	0	0	0	0	0	0	0	1	250.00	388.35	250.00	550.00
2	0	0	0	0	0	0	0	1	0	1	389.35	663.81	375.00	995.00
3	0	0	0	0	0	0	0	1	1	1	664.81	986.61	625.00	1515.00
4	0	0	0	0	0	0	1	1	1	1	987.61	1467.67	745.00	1835.00
5	0	0	0	0	1	0	1	1	1	1	1468.67	1767.82	795.00	1985.00
6	0	0	0	0	1	1	1	1	1	1	1768.82	1887.12	870.00	2265.00
7	0	0	0	1	1	1	1	1	1	1	1888.12	2246.93	895.00	2385.00
8	0	1	0	1	1	1	1	1	1	1	2247.93	2465.00	915.00	2465.00
9	0	1	1	1	1	1	1	1	1	1	2466.00	2565.00	945.00	2565.00
10	1	1	1	1	1	1	1	1	1	1	2566.00	2630.00	963.00	2630.00

Table 6.9: Order of Combination of Plant No. 2

Sr No.	unit status 1	2	3	4	5	6	7	8	Operattion Range Lower Mw	Higher Mw	Capacity $\sum Pmin_j$ Mw	$\sum Pmax_j$ Mw
1	0	0	0	0	0	0	0	1	250.00	388.35	250.00	550.00
2	0	0	0	0	0	1	0	1	389.35	663.81	375.00	995.00
3	0	0	0	0	0	1	1	1	664.81	986.61	625.00	1515.00
4	0	0	0	0	1	1	1	1	987.61	1467.67	745.00	1835.00
5	0	0	1	0	1	1	1	1	1468.67	1767.82	795.00	1985.00
6	0	0	1	1	1	1	1	1	1768.82	2135.77	870.00	2265.00
7	1	0	1	1	1	1	1	1	2136.77	2345.00	890.00	2345.00
8	1	1	1	1	1	1	1	1	2346.00	2445.00	920.00	2445.00

Table 6.10: Order of Combination of Plant No. 3

Sr	unit status						Operattion Range		Capacity	
No.	1	2	3	4	5	6	Lower Mw	Higher Mw	$\sum Pmin_j$ Mw	$\sum Pmax_j$ Mw
1	0	0	0	0	0	1	250.00	388.35	250.00	550.00
2	0	0	0	1	0	1	389.35	663.81	375.00	995.00
3	0	0	0	1	1	1	664.81	1428.35	625.00	1515.00
4	0	0	1	1	1	1	1429.35	1550.92	700.00	1795.00
5	0	1	1	1	1	1	1551.92	1915.00	725.00	1915.00
6	1	1	1	1	1	1	1916.00	1975.00	740.00	1975.00

Table 6.11: Order of Combination of Plant No. 4

Sr	unit status							Operattion Range		Capacity	
No.	1	2	3	4	5	6	7	Lower Mw	Higher Mw	$\sum Pmin_j$ Mw	$\sum Pmax_j$ Mw
1	0	0	0	0	0	0	1	250.00	388.35	550.00	250.00
2	0	0	0	0	0	1	1	389.35	661.99	995.00	375.00
3	0	0	0	0	1	1	1	662.99	1032.83	1315.00	495.00
4	0	0	1	0	1	1	1	1033.83	1291.82	1465.00	545.00
5	0	0	1	1	1	1	1	1292.82	1414.26	1745.00	620.00
6	0	1	1	1	1	1	1	1415.26	1715.26	1865.00	645.00
7	1	1	1	1	1	1	1	1716.26	1945.00	1945.00	665.00

Table 6.12: Order of Combination of Plant No. 5

Sr	unit status									Operattion Range		Capacity	
No.	1	2	3	4	5	6	7	8	9	Lower Mw	Higher Mw	$\sum Pmin_j$ Mw	$\sum Pmax_j$ Mw
1	0	0	0	0	0	0	0	0	1	250.00	500.00	250.00	550.00
2	0	0	0	0	0	0	0	1	1	501.00	683.81	500.00	1070.00
3	0	0	0	0	0	0	1	1	1	684.81	959.54	625.00	1515.00
4	0	0	0	0	0	1	1	1	1	960.54	1555.60	745.00	1835.00
5	0	0	0	1	0	1	1	1	1	1556.60	1854.60	795.00	1985.00
6	0	0	0	1	1	1	1	1	1	1855.60	1972.70	870.00	2265.00
7	0	0	1	1	1	1	1	1	1	1973.70	2335.13	895.00	2385.00
8	0	1	1	1	1	1	1	1	1	2336.13	2485.00	925.00	2485.00
9	1	1	1	1	1	1	1	1	1	2486.00	2545.00	940.00	2545.00

Table 6.13: unit commitment Schedule of Plant No. 1

Hour	system demand	plant Load	cost	status of units									
1	4250.00	986.606	1890.66	0	0	0	0	0	0	0	1	1	1
2	4500.00	1148.247	2218.37	0	0	0	0	0	0	1	1	1	1
3	4770.00	1196.732	2320.67	0	0	0	0	0	0	1	1	1	1
4	5000.00	1260.995	2459.09	0	0	0	0	0	0	1	1	1	1
5	5250.00	1331.635	2614.99	0	0	0	0	0	0	1	1	1	1
6	5890.00	1467.671	2926.23	0	0	0	0	0	0	1	1	1	1
7	6000.00	1467.671	2926.23	0	0	0	0	0	0	1	1	1	1
8	6300.00	1467.671	2926.23	0	0	0	0	0	0	1	1	1	1
9	6500.00	1767.821	3633.55	0	0	0	0	1	0	1	1	1	1
10	6800.00	1767.821	3633.55	0	0	0	0	1	0	1	1	1	1
11	7180.00	1767.821	3633.55	0	0	0	0	1	0	1	1	1	1
12	7500.00	2205.010	4701.85	0	0	0	1	1	1	1	1	1	1
13	8080.00	2246.926	4811.82	0	0	0	1	1	1	1	1	1	1
14	8700.00	2246.926	4811.82	0	0	0	1	1	1	1	1	1	1
15	9200.00	2465.000	5411.40	0	1	0	1	1	1	1	1	1	1
16	9700.00	2565.000	5675.88	0	1	1	1	1	1	1	1	1	1
17	9820.00	2630.00	5850.57	0	1	1	1	1	1	1	1	1	1
18	9200.00	2465.000	5411.40	0	1	0	1	1	1	1	1	1	1
19	8800.00	2465.000	5411.40	0	1	0	1	1	1	1	1	1	1
20	7900.00	2209.894	4714.51	0	0	0	1	1	1	1	1	1	1
21	7000.00	1767.821	3633.55	0	0	0	0	1	0	1	1	1	1
22	6500.00	1767.821	3633.55	0	0	0	0	1	0	1	1	1	1
23	5050.00	1275.057	2489.81	0	0	0	0	0	0	1	1	1	1
24	4500.00	1148.247	2218.37	0	0	0	0	0	0	1	1	1	1

total cost at plant 89917.91

Table 6.14: unit commitment Schedule of Plant No. 2

Hour	system demand	plant Load	cost	status of units							
1	4250.00	948.645	1812.59	0	0	0	0	0	1	1	1
2	4500.00	953.320	1822.14	0	0	0	0	0	1	1	1
3	4770.00	1107.813	2134.48	0	0	0	0	1	1	1	1
4	5000.00	1165.065	2253.65	0	0	0	0	1	1	1	1
5	5250.00	1227.731	2387.04	0	0	0	0	1	1	1	1
6	5890.00	1409.766	2791.98	0	0	0	0	1	1	1	1
7	6000.00	1458.719	2905.31	0	0	0	0	1	1	1	1
8	6300.00	1467.671	2926.23	0	0	0	0	1	1	1	1
9	6500.00	1467.671	2926.23	0	0	0	0	1	1	1	1
10	6800.00	1467.671	2926.23	0	0	0	0	1	1	1	1
11	7180.00	1767.821	3633.55	0	0	1	0	1	1	1	1
12	7500.00	1767.821	3633.55	0	0	1	0	1	1	1	1
13	8080.00	1935.591	4036.42	0	0	1	1	1	1	1	1
14	8700.00	2135.768	4544.97	0	0	1	1	1	1	1	1
15	9200.00	2300.916	4988.28	1	0	1	1	1	1	1	1
16	9700.00	2445.000	5385.28	1	1	1	1	1	1	1	1
17	9820.00	2445.000	5385.28	1	1	1	1	1	1	1	1
18	9200.00	2300.916	4988.28	1	0	1	1	1	1	1	1
19	8800.00	2135.768	4544.97	0	0	1	1	1	1	1	1
20	7900.00	1883.261	3908.95	0	0	1	1	1	1	1	1
21	7000.00	1767.821	3633.55	0	0	1	0	1	1	1	1
22	6500.00	1467.671	2926.23	0	0	0	0	1	1	1	1
23	5050.00	1177.561	2280.00	0	0	0	0	1	1	1	1
24	4500.00	953.320	1822.14	0	0	0	0	0	1	1	1

total cost at plant 80561.75

Table 6.15: unit commitment Schedule of Plant No. 3

Hour	system demand	plant Load	cost	status of units					
1	4250.00	919.231	1753.00	0	0	0	1	1	1
2	4500.00	926.042	1766.73	0	0	0	1	1	1
3	4770.00	962.151	1840.22	0	0	0	1	1	1
4	5000.00	1011.119	1941.77	0	0	0	1	1	1
5	5250.00	1064.699	2055.39	0	0	0	1	1	1
6	5890.00	1219.695	2398.71	0	0	0	1	1	1
7	6000.00	1261.372	2494.75	0	0	0	1	1	1
8	6300.00	1317.001	2625.39	0	0	0	1	1	1
9	6500.00	1297.393	2579.02	0	0	0	1	1	1
10	6800.00	1428.346	2895.31	0	0	0	1	1	1
11	7180.00	1428.346	2895.31	0	0	0	1	1	1
12	7500.00	1426.418	2890.54	0	0	0	1	1	1
13	8080.00	1550.924	3187.42	0	0	1	1	1	1
14	8700.00	1882.611	4017.00	0	1	1	1	1	1
15	9200.00	1905.963	4084.46	0	1	1	1	1	1
16	9700.00	1975.000	4276.90	1	1	1	1	1	1
17	9820.00	1975.000	4276.90	1	1	1	1	1	1
18	9200.00	1905.963	4084.46	0	1	1	1	1	1
19	8800.00	1835.775	3890.21	0	1	1	1	1	1
20	7900.00	1545.177	3173.46	0	0	1	1	1	1
21	7000.00	1428.346	2895.31	0	0	0	1	1	1
22	6500.00	1297.393	2579.02	0	0	0	1	1	1
23	5050.00	1021.805	1964.23	0	0	0	1	1	1
24	4500.00	926.042	1766.73	0	0	0	1	1	1

total cost at plant 68301.85

Table 6.16: unit commitment Schedule of Plant No. 4

Hour	system demand	plant Load	cost	status of units						
1	4250.00	780.473	1502.39	0	0	0	0	1	1	1
2	4500.00	785.681	1513.20	0	0	0	0	1	1	1
3	4770.00	818.607	1582.28	0	0	0	0	1	1	1
4	5000.00	862.215	1675.67	0	0	0	0	1	1	1
5	5250.00	910.120	1780.74	0	0	0	0	1	1	1
6	5890.00	1032.829	2061.77	0	0	0	0	1	1	1
7	6000.00	1032.829	2061.77	0	0	0	0	1	1	1
8	6300.00	1268.814	2615.80	0	0	1	0	1	1	1
9	6500.00	1246.246	2560.63	0	0	1	0	1	1	1
10	6800.00	1291.817	2672.63	0	0	1	0	1	1	1
11	7180.00	1291.817	2672.63	0	0	1	0	1	1	1
12	7500.00	1414.263	2964.25	0	0	1	1	1	1	1
13	8080.00	1659.134	3565.19	0	1	1	1	1	1	1
14	8700.00	1715.258	3710.80	0	1	1	1	1	1	1
15	9200.00	1945.000	4341.38	1	1	1	1	1	1	1
16	9700.00	1945.000	4341.38	1	1	1	1	1	1	1
17	9820.00	1945.000	4341.38	1	1	1	1	1	1	1
18	9200.00	1945.000	4341.38	1	1	1	1	1	1	1
19	8800.00	1715.258	3710.80	0	1	1	1	1	1	1
20	7900.00	1610.281	3441.39	0	1	1	1	1	1	1
21	7000.00	1291.817	2672.63	0	0	1	0	1	1	1
22	6500.00	1246.246	2560.63	0	0	1	0	1	1	1
23	5050.00	871.753	1696.38	0	0	0	0	1	1	1
24	4500.00	785.681	1513.20	0	0	0	0	1	1	1

total cost at plant 65872.50

Table 6.17: unit commitment Schedule of Plant No. 5

Hour	system demand	plant Load	cost	status of units								
1	4250.00	870.766	1666.65	0	0	0	0	0	0	1	1	1
2	4500.00	974.341	1876.35	0	0	0	0	0	1	1	1	1
3	4770.00	1010.585	1948.45	0	0	0	0	0	1	1	1	1
4	5000.00	1060.973	2050.43	0	0	0	0	0	1	1	1	1
5	5250.00	1115.902	2163.93	0	0	0	0	0	1	1	1	1
6	5890.00	1277.003	2510.82	0	0	0	0	0	1	1	1	1
7	6000.00	1320.825	2608.80	0	0	0	0	0	1	1	1	1
8	6300.00	1379.531	2742.48	0	0	0	0	0	1	1	1	1
9	6500.00	1350.743	2676.58	0	0	0	0	0	1	1	1	1
10	6800.00	1552.814	3153.23	0	0	0	0	0	1	1	1	1
11	7180.00	1738.101	3601.30	0	0	0	1	0	1	1	1	1
12	7500.00	1548.650	3143.08	0	0	0	0	0	1	1	1	1
13	8080.00	1713.515	3540.54	0	0	0	1	0	1	1	1	1
14	8700.00	1961.796	4161.14	0	0	0	1	1	1	1	1	1
15	9200.00	1979.146	4204.57	0	0	1	1	1	1	1	1	1
16	9700.00	2386.896	5267.75	0	1	1	1	1	1	1	1	1
17	9820.00	2497.213	5579.61	1	1	1	1	1	1	1	1	1
18	9200.00	1979.146	4204.57	0	0	1	1	1	1	1	1	1
19	8800.00	1904.562	4018.06	0	0	0	1	1	1	1	1	1
20	7900.00	1622.942	3320.24	0	0	0	1	0	1	1	1	1
21	7000.00	1499.242	3023.66	0	0	0	0	0	1	1	1	1
22	6500.00	1350.743	2676.58	0	0	0	0	0	1	1	1	1
23	5050.00	1071.945	2072.91	0	0	0	0	0	1	1	1	1
24	4500.00	974.341	1876.35	0	0	0	0	0	1	1	1	1

total cost at plant 74057.50
system total cost 378711.50

Table 6.18: unit commitment Schedule

Hour	Demand MW	Plant No	Plant Load MW	Unit Gen. in MW.									
1	4250 0	1	986.6	. 0	.0	.0	.0	.0	.0	.0	290 6	345.8	350.1
		2	948.6	.0	.0	.0	.0	.0	279.0	332.3	337.4	-	-
		3	19.2	.0	.0	.0	270.0	321.8	327.5	-	-	-	-
		4	780.5	.0	.0	.0	.0	140.0	290.5	350.0	-	-	-
		5	870.8	0	.0	.0	.0	.0	.0	246.5	309 0	315.3	-
10	6880	1	1767.8	.0	.0	.0	.0	150.0	.0	206 7	420.8	497.5	492 8
		2	1467.7	.0	.0	.0	.0	186.3	381.0	451.2	449.2	-	-
		3	1428.3	.0	.0	.0	426.1	503.7	498.6	-	-	-	-
		4	1291.8	.0	.0	150.0	.0	210.9	429.0	501.9	-	-	-
		5	1552.8	.0	.0	.0	.0	.0	203.4	388.2	482.5	478.7	-
17	9820	1	2630.0	65.0	80.0	100.0	120.0	150.0	280.0	320.0	445.0	520.0	550.0
		2	2445.0	80.0	100.0	150.0	280.0	320.0	445.0	520.0	550.0	-	-
		3	1975.0	60.0	120.0	280.0	445.0	520.0	550.0	-	-	-	-
		4	1945.0	80.0	120.0	150.0	280.0	320.0	445.0	550.0	-	-	-
		5	2497.213.0	60 0	100.0	120.0	150.0	255.96	296.25	445.0	520.0	550.0	

Table 6.19: unit commitment Schedule

Hour	Demand MW	Transmission Losses MW	Total Generation MW
1	4500.0	287.918	4787.918
10	6800.0	708.75	7508.75
17	9820.0	1672.908	11492.91

Table 6.20: Input Data for Plant 1:Nox Coefficients

Plant No	Unit No	Emission Eoefficients		
		e_{ij}	f_{ij}	g_{ij}
1	1	.00939	.73398	31.04487
	2	.01530	-1.22195	90.19784
	3	.01530	-1.22195	90.19784
	4	.01033	-1.14499	96.08599
	5	.01032	-1.14499	95.06660
	6	.00939	.73398	31.04487
	7	.01530	-1.22195	90.19784
	8	.01530	-1.22195	90.19784
	9	.01033	-1.14499	96.08599
	10	01033	-1.14499	96.08599

Table 6.21: Input Data for Plant 2 :Nox Coefficients

Plant No	Unit No	Emission Eoefficients		
		e_{ij}	f_{ij}	g_{ij}
2	1	.00939	.73388	32.04467
	2	.00939	.73388	32.04467
	3	.0153	-1.22195	90.19764
	4	.0153	-1.22195	90.19764
	5	.01033	-1.14499	96.08599
	6	.01530	-1.22195	90.19764
	7	.01033	-1.14499	96.08599
	8	.01033	-1.14499	96.08599

Table 6.22: Input Data for Plant 3 :Nox Coefficients

Plant No	Unit No	Emission Eoefficients		
		e_{ij}	f_{ij}	g_{ij}
3	1	.01033	-1.14499	96.08599
	2	.00939	.73398	0 31.04487
	3	.00939	.73398	31.04487
	4	.01530	-1.22195	90.19784
	5	.01033	-1.14499	96.08599
	6	.01033	-1.14499	96.08599

Table 6.23: Input Data for Plant 4:Nox Coefficients

Plant No	Unit No	Emission Eoefficients		
		e_{ij}	f_{ij}	g_{ij}
4	1	.01033	-1.14499	96.08599
	2	.00939	.73398	31.04487
	3	.00939	.73398	31.04487
	4	.01530	-1.22195	90.19784
	5	.01033	-1.14499	96.08599
	6	.00939	.73398	31.04487
	7	.01530	-1.22195	90.19784

Table 6.24: Input Data for Plant 5:Nox Coefficients

Plant No	Unit No	Emission Eoefficients		
		e_{ij}	f_{ij}	g_{ij}
5	1	.01033	-1.14499	96.08599
	2	.00939	.73398	31.04487
	3	.00939	.73398	31.04487
	4	.01530	-1.22195	90.19784
	5	.01530	-1.22195	90.19764
	6	.01033	-1.14499	96.08599
	7	.01033	-1.14499	96.08599
	8	.01033	-1.14499	96.08599
	9	.00939	.73398	31.04487

i is the index for plant and j for unit

Table 6.25: Emission Constrained unit commitment:Specified Nox Level

Plant No	1	2	3	4	5
specified Nox Level	9200.0	8900.0	9100.0	8200.0	9000.0

Table 6.26: Emission Constrained Plant wise combination Order:Plant 1

stage No	Unit status										Operation Range			
											Economic		Env constrained)	
											Lower MW	Upper MW	Lower MW	upper MW
1	0	0	0	0	0	0	0	0	0	1	250.00	388.53	250.00	388.53
2	0	0	0	0	0	0	0	1	0	1	389.35	663.81	389.35	663.80
3	0	0	0	0	0	0	0	1	1	1	64.81	986.61	664.80	986.61
4	0	0	0	0	0	0	1	1	1	1	987.61	1467.67	987.60	1467.67
5	0	0	0	0	1	0	1	1	1	1	1468.67	1767.82	1468.67	1767.82
6	0	0	0	0	1	1	1	1	1	1	1768.82	1887.12	1768.82	1887.12
7	0	0	0	1	1	1	1	1	1	1	1888.12	2246.93	1888.11	2246.93
8	0	1	0	1	1	1	1	1	1	1	2247.93	2465.00	2247.92	2389.06
9	0	1	1	1	1	1	1	1	1	1	2466.00	2565.00	2390.06	2477.06
10	1	1	1	1	1	1	1	1	1	1	2566.00	2630.00	2478.06	2530.145

Table 6.27: Emission Constrained Plant wise combination Order:Plant 2

stage No	Unit status								Operation Range			
									Economic		Env constrained)	
									Lower MW	Upper MW	Lower MW	upper MW
1	0	0	0	0	0	0	0	1	250.00	388.35	250.00	388.35
2	0	0	0	0	0	1	0	1	389.35	663.81	389.35	663.80
3	0	0	0	0	0	1	1	1	664.81	986.61	664.80	986.60
4	0	0	0	0	1	1	1	1	987.61	1467.67	987.60	1467.67
5	0	0	1	0	1	1	1	1	1468.67	1767.82	1468.67	1767.82
6	0	0	1	1	1	1	1	1	1768.82	2135.77	1768.82	2135.77
7	1	0	1	1	1	1	1	1	2136.77	2345.00	2136.768	2284.07
8	1	1	1	1	1	1	1	1	2346.00	2445.00	2285.076	2364.674

Table 6.28: Emission Constrained Plant wise combination Order:Plant 3

stage No	Unit status						Operation Range			
							Economic		Env constrained)	
							Lower MW	Upper MW	Lower MW	upper MW
1	0	0	0	0	0	1	250.00	388.35	250.00	388.35
2	0	0	0	1	0	1	389.35	663.81	389.35	663.81
3	0	0	0	1	1	1	664.81	1428.35	664.81	1428.35
4	0	0	1	1	1	1	1429.35	1550.92	1429.34	1550.92
5	0	1	1	1	1	1	1551.92	1915.00	1551.92	1915.00
6	1	1	1	1	1	1	1916.00	1975.00	1916.00	1975.00

Table 6.29: Emission Constrained Plant wise combination Order:Plant 4

stage No	Unit status							Operation Range			
								Economic		Env constrained)	
								MW	MW	MW	MW
1	0	0	0	0	0	0	1	250.00	388.35	250.00	388.35
2	0	0	0	0	0	1	1	389.35	661.99	389.35	661.99
3	0	0	0	0	1	1	1	662.99	1032.83	662.99	1032.83
4	0	0	1	0	1	1	1	1033.83	1291.82	1033.83	1291.82
5	0	0	1	1	1	1	1	1292.82	1414.26	1292.82	1414.26
6	0	1	1	1	1	1	1	1415.26	1715.26	1415.26	1715.26
7	1	1	1	1	1	1	1	1716.26	1945.00	1716.26	1945.00

Table 6.30: Emission Constrained Plant wise combination Order:Plant 5

stage No	Unit status									Operation Range			
										Economic		Env constrained	
										Lower MW	Upper MW	Lower MW	upper MW
1	0	0	0	0	0	0	0	0	1	250.00	500.00	250.00	500.00
2	0	0	0	0	0	0	0	1	1	501.00	683.81	501.00	683.80
3	0	0	0	0	0	0	1	1	1	684.81	959.54	684.81	959.54
4	0	0	0	0	0	1	1	1	1	960.54	1555.60	960.54	1555.60
5	0	0	0	1	0	1	1	1	1	1556.60	1854.60	1556.60	1854.60
6	0	0	0	1	1	1	1	1	1	1855.60	1972.70	1855.60	1972.70
7	0	0	1	1	1	1	1	1	1	1973.70	2335.13	1973.70	2335.13
8	0	1	1	1	1	1	1	1	1	2336.13	2485.00	2336.13	2423.97
9	1	1	1	1	1	1	1	1	1	2486.00	2545.00	2424.97	2477.41

Table 6.31: unit commitment Schedule of Plant

Hour	System Demand MW	Plant No	Plant Load MW	Nox Constrained Plant Capacity MW	Status of units									
1	6000	1	1321.26	1467.67	0	0	0	0	0	0	1	1	1	1
		2	1321.26	1467.67	0	0	0	0	1	1	1	1 -	-	
		3	1154.79	1428.35	0	0	0	1	1	1				
		4	915.32	1032.83	0	0	0	0	1	1	1	0	0	
		5	1287.37	1555.6	0	0	0	0	0	1	1	1	1	
2	7700	1	1681.73	1767.82	0	0	0	0	1	0	1	1	1	1
		2	1681.73	1767.82	0	0	1	0	1	1	1	1-	-	
		3	1344.60	1428.35	0	0	0	1	1	1	-	-	-	-
		4	1373.36	1414.26	0	0	1	1	1	1	1	-	-	-
		5	1618.59	1854.60	0	0	0	1	0	1	1	1	1	-
3	8000	1	1879.38	1887.12	0	0	0	0	1	1	1	1	1	1
		2	1710.36	1767.82	0	0	1	0	1	1	1	1		
		3	1365.49	1550.92	0	0	0	1	1	1				
		4	1398.17	1414.26	0	0	1	1	1	1	1			
		5	1646.60	1854.6	0	0	0	1	0	1	1	1	1	
4	9760	1	2176.89	2246.93	0	0	0	1	1	1	1	1	1	1
		2	2068.01	2135.77	0	0	1	1	1	1	1	1		
		3	1786.71	1915.0	0	1	1	1	1	1				
		4	1652.05	1715.26	0	1	1	1	1	1	1			
		5	2076.34	2335.13	0	0	1	1	1	1	1	1	1	
5	11000	1	2530.15	2530.15	1	1	1	1	1	1	1	1	1	1
		2	2364.67	2364.67	1	1	1	1	1	1	1	1		
		3	1915.00	1915.0	0	1	1	1	1	1				
		4	1945.00	1945	1	1	1	1	1	1	1			
		5	2245.18	2335.97	0	0	1	1	1	1	1	1	1	

Table 6.32: Unit Commitment Due to Security

Hour	Demand MW	Plant No	Units Status									
1	6000.0	1	0	0	0	0	1	0	1	1	1	1
		2	0	0	1	0	1	1	1	1		
		3	0	0	1	1	1	1				
		4	0	0	1	1	1	1	1			
		5	0	0	0	1	1	1	1	1	1	
2	7700.0	1	0	0	0	0	0	1	1	1	1	1
		2	0	0	1	1	1	1	1	1		
		3	0	1	1	1	1	1				
		4	1	1	1	1	1	1	1			
		5	0	0	1	1	1	1	1	1	1	
3	8000.0	1	0	1	0	1	1	1	1	1	1	1
		2	0	0	1	1	1	1	1	1		
		3	0	1	1	1	1	1				
		4	1	1	1	1	1	1	1			
		5	0	0	1	1	1	1	1	1	1	
4	9760.0	1	0	1	1	1	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1		
		3	1	1	1	1	1	1				
		4	1	1	1	1	1	1	1			
		5	1	1	1	1	1	1	1	1	1	
5	11000.0	1	1	1	1	1	1	1	1	1	1	1
		2	1	1	1	1	1	1	1	1		
		3	1	1	1	1	1	1				
		4	1	1	1	1	1	1	1			
		5	1	1	1	1	1	1	1	1	1	

Total Cost is 386450.40

Table 6.33: Unit Commitment Due to Security and Env Constrained Dispatch

Hour	Demand MW	Plant No	Plant Load	Esimated Nox	Specifien NOx
1	6000.0	1	1265.092	3604.01	9200.0
		2	1265.092	3529.57	8900.0
		3	1153.277	3522.73	9100.0
		4	1012.469	3299.63	8200.0
		5	1390.0	3907.21	9000.0
2	7700.0	1	1646.595	5395.441	9200.0
		2	1646.595	5211.567	8900.0
		3	1434.11	5091.39	9100.0
		4	1341.766	4756.253	8200.0
		5	1630.932	4936.37	9000.0
3	8000.0	1	1810.289	7562.886	9200.0
		2	1682.338	5400.0	8900
		3	1464.02	5306.0	9100.0
		4	1374.64	4945.027	8200.0
		5	1668.711	5137.261	9000.0
4	9760.0	1	2211.576	7909.5	9200.0
		2	2110.275	7731.945	8900.0
		3	1730.35	7272.832	9100.0
		4	1630.834	6588083	8200.0
		5	2076.965	7153.13	9000.0
5	11000.0	1	2530.145	9200.0	9200.0
		2	2364.674	8899.999	8900.0
		3	1906.491	8441.695	9100.0
		4	1816.119	7967.191	8200.0
		5	2382.572	8884.26	9000.0

Total Cost is 411305.8

Table 6.34: Result Of Unit Commitment Of Mix System.

hour	Demand MW	Generation in MW						
		Thermal Plant					Hydro Plant	Gas Plant
		1	2	3	4	5	1	1
1	6700.00	1316.77	1316.77	1150.91	1011.62	1316.77	165.45	421.73
2	6870.00	1431.07	1329.34	1161.78	1022.63	1329.34	166.92	428.92
3	6970.00	1452.17	1347.15	1177.17	1038.24	1347.15	169.01	439.11
4	7200.00	1477.71	1368.70	1195.79	1057.12	1477.71	171.53	451.44
5	7505.00	1516.51	1516.51	1224.10	1085.81	1516.51	175.37	470.18
6	7800.00	1574.92	1574.92	1266.70	1129.00	1574.92	181.15	498.39
7	7940.00	1605.22	1605.22	1288.80	1151.40	1605.22	184.14	500.00
8	8300.00	1772.27	1615.30	1296.15	1315.83	1615.30	185.14	500.00
9	8400.00	1795.64	1636.05	1311.28	1333.79	1636.05	187.19	500.00
10	8600.00	1804.84	1644.21	1317.24	1340.87	1804.84	188.00	500.00
11	8700.00	1827.62	1664.42	1331.98	1358.37	1827.62	190.00	500.00
12	8870.00	1861.39	1775.03	1455.22	1317.95	1775.03	185.38	500.00
13	10590.00	2166.67	2098.09	1811.89	1646.67	2166.67	200.00	500.00
14	12240.00	2630.00	2445.00	1975.00	1945.00	2545.00	200.00	500.00
15	11040.00	2352.99	2156.27	1847.03	1795.68	2188.03	200.00	500.00
16	9210.00	1898.56	1809.54	1481.44	1433.49	1898.56	188.41	500.00
17	9000.00	1871.24	1784.18	1462.17	1412.04	1784.18	186.19	500.00
18	8000.00	1618.36	1618.36	1298.38	1161.11	1618.36	185.44	500.00
19	7630.00	1541.26	1541.26	1242.15	1104.11	1541.26	177.82	482.13
20	7400.00	1495.72	1495.72	1208.93	1070.44	1495.72	173.32	460.14
21	7300.00	1498.14	1385.94	1210.69	1072.23	1498.14	173.55	461.31
22	6930.00	1443.73	1340.03	1171.01	1032.00	1340.03	168.17	435.04
23	6000.00	1202.26	1202.26	1051.94	833.07	1202.26	152.03	356.20
24	5900.00	1183.19	1183.19	1035.46	819.89	1183.19	149.79	345.29

Water Used 136000.01100 cu. Ft.
Water availabe 136000.000 in cu. ft
Gas Used 80x10^6 cu. ft
Gas Available 80x10^6 cu. ft

Table 6.35: Unit Commitment Of Mix System.

Hour	Demand MW	plant No	Plant Load MW	Status Of Units									
1	6700.00	1	1316.77	0	0	0	0	0	0	1	1	1	1
8	8300.00		1772.27	0	0	0	0	1	1	1	1	1	1
14	12240.00		2630.00	1	1	1	1	1	1	1	1	1	1
19	7630.00		1541.26	0	0	0	0	1	0	1	1	1	1
24	5900.00		1183.19	0	0	0	0	0	0	1	1	1	1
1	6700.00	2	1316.77	0	0	0	0	1	1	1	1	-	-
8	8300.00		1615.30	0	0	1	0	1	1	1	1	-	-
14	12240.00		2445.00	1	1	1	1	1	1	1	1	-	-
19	7630.00		1541.26	0	0	1	0	1	1	1	1	-	-
24	5900.00		1183.19	0	0	0	0	1	1	1	1	-	-
1	6700.00	3	1150.91	0	0	0	1	1	1	-	-	-	-
8	8300.00		1296.15	0	0	0	1	1	1	-	-	-	-
14	12240.00		1975.00	1	1	1	1	1	1	-	-	-	-
19	7630.00		1242.15	0	0	0	1	1	1	-	-	-	-
24	5900.00		1035.46	0	0	0	1	1	1	-	-	-	-
1	6700.00	4	1011.62	0	0	0	0	1	1	1	-	-	-
8	8300.00		1315.83	0	0	1	1	1	1	1	-	-	-
14	12240.00		1945.00	1	1	1	1	1	1	1	-	-	-
19	7630.00		1104.11	0	0	1	0	1	1	1	-	-	-
24	5900.00		819.89	0	0	0	0	1	1	1	-	-	-
1	6700.00	5	1316.77	0	0	0	0	0	1	1	1	1	-
8	8300.00		1615.30	0	0	0	1	0	1	1	1	1	-
14	12240.00		2545.00	1	1	1	1	1	1	1	1	1	-
19	7630.00		1541.26	0	0	0	1	0	1	1	1	1	-
24	5900.00		1183.19	0	0	0	0	0	1	1	1	1	-

Above UC Table is shown for selected Hours.

Table 6.36: Env Constrained Unit Commitment Schedule of Mix System:

hour	Demand MW	Generation in MW						
		Thermal Plant					Hydro Plant	Gas Plant
		1	2	3	4	5	1	1
1	6600.0	1287.02	1287.02	1125.20	985.55	1287.02	170.78	457.39
2	6870.0	1417.94	1318.26	1152.20	1012.92	1318.26	174.54	475.85
3	4970.0	995.36	995.36	873.12	690.06	995.36	135.69	285.02
4	7200.0	1464.82	1357.82	1186.39	1047.59	1464.82	179.30	499.23
5	7505.0	1507.97	1507.97	1217.87	1079.50	1507.98	183.69	500.00
6	7800.0	1572.52	1572.52	1264.95	1127.22	1572.52	190.24	500.00
7	7940.0	1603.15	1603.15	1287.29	1149.87	1603.15	193.35	500.00
8	8300.0	1770.06	1613.34	1294.72	1314.13	1613.34	194.39	500.00
9	8400.0	1793.42	1634.07	1309.84	1332.08	1634.07	196.49	500.00
10	7000.0	1445.27	1341.32	1172.13	1033.13	1341.32	177.32	489.48
11	8700.0	1825.43	1662.48	1330.56	1356.69	1825.43	199.38	500.00
12	8870.0	1859.22	1773.01	1453.68	1316.40	1773.01	194.65	500.00
13	11300.0	2476.85	2174.17	1914.70	1828.23	2206.03	200.00	500.00
14	11000.0	2342.90	2150.81	1837.99	1785.74	2182.54	200.00	500.00
15	6910.0	1426.35	1325.36	1158.33	1019.14	1325.36	175.40	480.05
16	6100.0	1209.91	1209.91	1058.55	838.36	1209.91	161.51	411.82
17	6740.0	1312.70	1312.70	1147.39	1008.05	1312.70	173.87	472.57
18	6000.0	1190.93	1190.93	1042.14	825.23	1190.93	159.22	400.60
19	7630.0	1535.33	1535.33	1237.82	1099.72	1535.33	186.46	500.00
20	7400.0	1485.00	1485.00	1201.11	1062.51	1485.00	181.35	500.00
21	7300.0	1487.30	1376.79	1202.79	1064.21	1487.30	181.59	500.00
22	6930.0	1430.55	1328.90	1161.40	1022.25	1328.90	175.82	482.14
23	6000.0	1190.93	1190.93	1042.14	825.23	1190.93	159.22	400.60
24	5900.0	1171.94	1171.94	1025.73	812.11	1171.94	156.94	389.38

Total Cost Of Thermal Generation Rs 329058.50

Table 6.37: Env Constrained Unit Commitment Schedule of Mix System:

Hour	Demand MW	Plant No	Plant Load MW	Unit Status									
1	6600.00	1	1287.02	0	0	0	0	0	0	1	1	1	1
8	8300.00		1770.07	0	0	0	0	1	1	1	1	1	1
13	11300.00		2476.85	1	1	1	1	1	1	1	1	1	1
14	11000.00		2342.91	0	1	0	1	1	1	1	1	1	1
20	7400.00		1485.01	0	0	0	0	1	0	1	1	1	1
24	5900.00		1171.94	0	0	0	0	0	0	1	1	1	1
1	6600.00	2	1287.02	0	0	0	0	1	1	1	1	-	-
8	8300.00		1613.35	0	0	1	0	1	1	1	1	-	-
13	11300.00		2174.18	1	0	1	1	1	1	1	1	-	-
14	11000.00		2150.81	1	0	1	1	1	1	1	1	-	-
20	7400.00		1485.01	0	0	1	0	1	1	1	1	-	-
24	5900.00		1171.94	0	0	0	0	1	1	1	1	-	-
1	6600.00	3	1125.2	0	0	0	1	1	1	-	-	-	-
8	8300.00		1294.72	0	0	0	1	1	1	-	-	-	-
13	11300.00		1914.70	1	1	1	1	1	1	-	-	-	-
14	11000.00		1837.99	0	1	1	1	1	1	-	-	-	-
20	7400.00		1201.12	0	0	0	1	1	1	-	-	-	-
24	5900.00		1025.74	0	0	0	1	1	1	-	-	-	-
1	6600.00	4	985.56	0	0	0	0	1	1	1	-	-	-
8	8300.00		1314.13	0	0	1	1	1	1	1	-	-	-
13	11300.00		1828.23	1	1	1	1	1	1	1	-	-	-
14	11000.00		1785.75	1	1	1	1	1	1	1	-	-	-
20	7400.00		1062.52	0	0	1	0	1	1	1	-	-	-
24	5900.00		812.11	0	0	0	0	1	1	1	-	-	-
1	6600.00	5	1287.02	0	0	0	0	0	1	1	1	1	-
8	8300.00		1613.35	0	0	0	1	0	1	1	1	1	-
13	11300.00		2206.04	0	0	1	1	1	1	1	1	1	-
14	11000.00		2182.54	0	0	1	1	1	1	1	1	1	-
20	7400.00		1485.01	0	0	0	1	0	1	1	1	1	-
24	5900.00		1171.94	0	0	0	0	0	1	1	1	1	-

Table 6.38: Env Constrained Unit Commitment Schedule of Mix System: Security

Hour	Demand MW	Plant No	Plant Load MW	Unit Status									
1	6600.00	1	1287.02300	0	0	0	1	0	0	1	1	1	1
8	8300.00		1770.06600	0	0	1	0	1	1	1	1	1	1
13	11300.00		2476.85200	1	1	1	1	1	1	1	1	1	1
14	11000.00		2342.90900	1	1	0	1	1	1	1	1	1	1
20	7400.00		1485.00500	0	0	0	0	1	0	1	1	1	1
24	5900.00		1171.94400	0	0	0	0	0	0	1	1	1	1
1	6600.00	2	1287.023	0	0	0	1	1	1	1	1	-	
8	8300.00		1613.34700	0	0	1	0	1	1	1	1		
13	11300.00		2174.17900	1	1	1	1	1	1	1	1		
14	11000.00		2150.81100	1	1	1	1	1	1	1	1		
20	7400.00		1485.00500	0	0	1	0	1	1	1	1		
24	5900.00		1171.94400	0	0	0	0	1	1	1	1		
1	6600.00	3	1125.20100	0	0	0	1	1	1	-	-	-	-
8	8300.00		1294.72400	0	0	0	1	1	1	-	-	-	-
13	11300.00		1914.70200	1	1	1	1	1	1	-	-	-	-
14	11000.00		1837.99200	0	1	1	1	1	1	-	-	-	-
20	7400.00		1201.11600	0	0	0	1	1	1	-	-	-	-
24	5900.00		1025.73900	0	0	0	1	1	1	-	-	-	-
1	6600.00	4	985.55570	0	0	0	0	1	1	1	-	-	-
8	8300.00		1314.13000	0	0	1	1	1	1	1	-	-	-
13	11300.00		1828.23100	1	1	1	1	1	1	1	-	-	-
14	11000.00		1785.74600	1	1	1	1	1	1	1	-	-	-
20	7400.00		1062.51500	0	0	1	1	1	1	1	-	-	-
24	5900.00		812.11440	0	0	0	0	1	1	1	-	-	-
1	6600.00	5	1287.02300	0	0	0	1	1	1	1	1	1	-
8	8300.00		1613.34700	0	0	1	1	1	1	1	1	1	-
13	11300.00		2206.03500	1	1	1	1	1	1	1	1	1	-
14	11000.00		2182.54200	1	1	1	1	1	1	1	1	1	-
20	7400.00		1485.00500	0	0	1	1	1	1	1	1	1	-
24	5900.00		1171.94400	0	0	0	1	1	1	1	1	1	-

Table 6.39: Post Security Assessed Unit commitment Schedule of Mix System

hour	Demand MW	Generation in MW						
		Thermal Plant					Hydro Plant	Gas Plant
		1	2	3	4	5	1	1
1	6600.0	1285.07	1343.55	1072.06	849.16	1426.08	168.18	455.86
2	6870.0	1407.47	1379.17	1098.83	870.56	1467.42	171.96	474.55
3	4970.0	963.74	963.74	845.79	668.20	1094.46	136.22	297.81
4	7200.0	1431.47	1400.61	1114.93	1100.61	1492.31	174.24	485.80
5	7505.0	1432.92	1432.92	1163.13	1157.85	1637.11	181.04	500.00
6	7800.0	1137.40	1583.87	1273.23	1288.60	1820.28	196.59	500.00
7	7940.0	1160.05	1613.87	1295.11	1314.58	1856.68	199.69	500.00
8	8300.0	1408.83	1642.99	1316.34	1339.81	1892.01	200.00	500.00
9	8400.0	1429.05	1663.93	1331.62	1357.95	1917.43	200.00	500.00
10	7000.0	1391.16	1364.60	1087.88	1068.48	1450.52	170.42	466.91
11	8700.0	1525.12	1698.82	1357.07	1388.17	2030.79	200.00	500.00
12	8870.0	1491.78	1830.58	1497.42	1360.65	1989.56	200.00	500.00
13	11300.0	2038.46	2374.51	1936.63	1881.24	2369.14	200.00	500.00
14	11000.0	1887.12	2359.72	1880.15	1832.09	2340.91	200.00	500.00
15	6910.0	1415.98	1386.77	1104.54	875.13	1476.25	172.77	478.54
16	6100.0	1168.13	1168.13	1022.44	809.48	1349.42	161.17	421.20
17	6740.0	1311.37	1370.99	1092.68	865.65	1457.93	171.09	470.26
18	6000.0	1150.33	1150.33	1007.05	797.17	1325.65	159.00	410.45
19	7630.0	1109.91	1547.45	1246.66	1257.05	1776.08	192.84	500.00
20	7400.0	1411.55	1411.55	1147.54	1139.33	1611.17	178.84	500.00
21	7300.0	1385.39	1418.61	1128.46	1116.67	1579.44	176.15	495.25
22	6930.0	1420.23	1390.57	1107.39	877.41	1480.66	173.17	480.50
23	6000.0	1150.33	1150.33	1007.05	797.17	1325.65	159.00	410.45
24	5900.0	1132.52	1132.52	991.66	784.86	1301.87	156.82	399.70

Water available 136000 cu ft

Water used 136000.41 cu ft

Gas available 80x10^6 cu ft

Gas Consumed 80x10^6 cu ft

No of iteration 7

Table 6.40: Generation of Units at Plant No 1

Hour	Demand	Plant	Unit Generation									
1	6600.0	1285.07	0.0	0.0	0.0	59.5	0.0	0.0	153.4	316.8	376.3	378.8
8	8300.0	1408.83	0.0	0.0	34.2	0.0	75.3	112.2	148.2	306.6	364.4	367.6
13	11300.0	2038.46	25.7	57.4	66.1	88.3	134.4	160.1	191.5	391.1	463.0	460.3
14	11000.0	1887.1	21.7	52.2	0.0	82.9	124.6	152.2	184.3	377.1	446.7	445.0
20	7400.0	1411.55	0.0	0.0	0.0	0.0	98.6	0.0	165.3	339.9	403.3	404.2
24	5900.00	1132.52	0.0	0.0	0.0	0.0	0.0	0.0	140.8	292.1	347.6	351.8

Table 6.41: Generation of Units at Plant No 2

Hour	Demand	Plant	Unit Generation							
1	6600.0	1343.5	0.0	0.0	0.0	118.0	153.4	316.8	376.3	378.8
8	8300.0	1642.9	0.0	0.0	134.8	0.0	191.8	391.7	463.6	460.9
13	11300.0	2374.5	80.0	100.0	150.0	253.5	275.9	445.0	520.0	550.0
14	11000.0	2359.7	80.0	100.0	150.0	245.8	268.9	445.0	520.0	550.0
20	7400.0	1411.5	0.0	0.0	98.6	0.0	165.3	339.9	403.3	404.2
24	5900.0	1132.5	0.0	0.0	0.0	0.0	140.8	292.1	347.6	351.83

Table 6.42: Generation of Units at Plant No 3

Hour	Demand	Plant	Unit Generation									
1	6600.0	1072.0	0.0	0.0	0.0	316.8	376.3	378.8	-	-	-	-
8	8300.0	1316.3	0.0	0.0	0.0	391.7	463.6	460.9	-	-	-	-
13	11300.0	1936.6	58.7	120.0	242.8	445.0	520.0	550.0	-	-	-	-
14	11000.0	1880.1	0.0	120.0	245.1	445.0	520.0	550.0	-	-	-	-
20	7400.0	1147.5	0.0	0.0	0.0	339.9	403.3	404.2	-	-	-	-
24	5900.0	991.6	0.0	0.0	0.0	292.1	347.6	351.8	-	-	-	-

Table 6.43: Generation of Units at Plant No 4

Hour	Demand	Plant	Unit Generation						
1	6600.0	849.1	0.0	0.0	0.0	0.0	153.4	316.8	378.8
8	8300.0	1339.8	0.0	0.0	134.8	160.4	191.8	391.7	460.9
13	11300.0	1881.2	80.0	120.0	150.0	257.1	279.1	445.0	550.0
14	11000.0	1832.0	80.0	120.0	150.0	231.2	255.7	445.0	550.0
20	7400.0	1139.3	0.0	0.0	98.6	131.1	165.3	339.9	404.2
24	5900.0	784.8	0.0	0.0	0.0	0.0	140.8	292.1	351.8

Table 6.44: Generation of Units at Plant No 5

Hour	Demand	Plant	Unit Generation								
1	6600.0	1426.0	0.0	0.0	0.0	82.5	118.0	153.4	316.8	376.3	378.8
8	8300.0	1892.0	0.0	0.0	88.5	134.8	160.4	191.8	391.7	463.6	460.9
13	11300.0	2369.1	41.3	98.4	120.0	150.0	208.8	235.4	445.0	520.0	550.0
14	11000.0	2340.9	38.3	94.4	117.4	150.0	202.8	230.0	445.0	520.0	542.8
20	7400.0	1611.1	0.0	0.0	68.4	98.6	131.1	165.3	339.9	403.3	404.2

Table 6.45: Generation

Hour	Demand MW	Plant No	Plant Load	Nox Estimated	Nox Estimated	Cost of Gen Rs	Remark
1	6600.0	1	1285.07	3839.966	9000.0	2528.87	No Limit Violation
13	11300.0	1	2038.46	6705.57		4324.47	No Limit Violation
14	11000.0		1887.12	6133.99		3944.52	No Limit Violation
1	6600.0	2	1343.55	3835.13	9000.00	2671.87	No Limit Violation
13	11300.0		2374 51	9393.5		5176.31	limit violation
14	11000.0		2359.32	9312.13		5134.32	limit violation
1	6600.0	3	1072.068	3512 37	8300.00	2071.21	No Limit Violation
13	11300.0	3	1936.63	8543.18	8300.00	4165.75	limit violation
14	11000.0		1880.15	8490.94		4010.0	limt violation
1	6600.0	4	849.16	3193.14	9230.0	1647.49	No Limit Violation
13	11300.0	4	1881 24	8309.661		4151.71	No Limit Violation
14	11000.0		1832 09	8046.037		4013.59	No Limit Violation
1	6600 0	5	1426 08	3971.96	9700.0	2863.98	No Limit Violation
13	11300.0	5	2369.14	8869 043		5140.46	No Limit Violation
14	11000.0		2340.91	8722.92		5066.84	No Limit Violation
14	11000 0		2340.91	8722.92		5066.84	No Limit Violation

6.6 Conclusion

An attempt is made to obtain unit commitment schedule of a thermal as well as a mix system. The procedure is based upon the developments proposed in preceding Chapters. For each system, two types of problems are solved. The first is the unit commitment & schedule, and the second is the emission constrained unit commitment & schedule. In latter problems, Patton's security function is used to ensure the reliability of thermal units. A special feature of the methodology is inclusion of emission constraint on unit commitment. The procedure initiates with formation of optimal combination order based on economical aspects. Each combination order is assigned a range of operation. Upper range of operation of each combination is checked against emission level and if necessary the upper range is reduced to an extent which may restrict the emission to the expected level. A procedure is developed to correct the upper range of each combination order. In short, the procedure of units' selection to form a combination order is based on economy whereas the range of operation of each combination is decided by specified emission level. Unit commitment of mix generation system is iterative in nature because of convergence required to ensure consumption and/or utilization of available volume of gas and water. From solutions obtained for each systems, the following points are worth noting.

(1) Using dynamic programming, the solution of unit commitment can be obtained for any number of units.

(2) The methodology is quite flexible to include emission constraint.

(3) The methodology is capable of including sources like hydro and gas provided consumption and/or discharge functions are quadratic like cost function of thermal system.

(4) As discussed in previous section, the algorithm developed not only controls maximum output of a plant due to specified emission level but also takes care to adjust the generation of each unit at a plant applying trade off technique thus ensuring economic operation.

(5) Basically, the entire procedure is of decomposition type. The main problem consisting of number of units is decmoposed into small probpems called subproblems. The subproblems are formed by grouping of units called plants(which is a reality). Each subproblem is solved independently, the solution of these problems is again used to link with the main problem; and finally, the solution of the main problem is obtained. The link between main and subproblems is the system demand. Naturally, the procedure is iterative in nature. In each iteration, for a given demand, a solution is sought at plant level and the total cost is evaluated at system level and tested for convergence.

Table 6.46: Cost Comparison of NOx Controlled Plants for Plant No.2

Generation of Units at Plant before Nox Control Controlfor Deamad No 13	80.0	100.0	150 0	253.59	275.9	445.0	520 0	550 0	
Total Nox									9393.5
Total Cost									5176.31
Generation of Plant after Nox Control for Deamad No 13	80.0	100.0	150.0	280.0	320.0	374.51	520 0	550.0	-
Total Nox									9000.042
Total Cost									5214.25

No iterations are 15

Table 6.47: Cost Comparison of NOx Controlled Plants for Plant No.2

Generation of Plant before Nox Control for Deamad No 14	80.0	100.0	150.0	253.59	275.9	445.0	520.0	550.0	-
Total Nox									9312.5
Total Cost									5134.32
Generation of Plant after Nox Control for Deamad No 14	80.0	100.0	150.0	280.0	320.0	374.51	520.0	550.0	
Total Nox									8999.998
Total Cost									5154 77

No of Iteration required are 5

Table 6.48: Cost Comparison of NOx Controlled Plants for Plant No.3

Generation of Plant before Nox Control for Deamad No 13	58.79	120.0	242.84	445.0	520.0	550.0	-	-	-	-
Total Nox									8543.18	
Total Cost									4165.75	
Generation of Plant after Nox Control for Deamad No 13	60.0	120.0	280.0	406.67	520.0	549.96	-	-	-	-
Total Nox									8300.014	
Total Cost									4181.98	

No of Iteration required are 5

Table 6.49: Cost Comparison of NOx Controlled Plants for Plant No.3

Generation of Plant before Nox Control for Deamad No 14	0.0	120.0	245.15	445.0	520.0	550.0	-	-	-	-
Total Nox									8490.94	
Total Cost									4010.15	
Generation of Plant after Nox Control for Deamad No 14	00.0	120.0	276.964	419.47	520.0	543.71	-	-	-	-
Total Nox									8300.004	
Total Cost									4022.24	

No of Iteration required are 9

(6) The methodology does not take into account reserve margin which is normally considered in unit commitment program. However, the care is taken to ensure sufficieny of generation by assessing Maximum Intolerable Security Level (MISL) for each combination order of thermal units.