Chapter 7

Conclusion

7.1 General

The aim of this chapter is to highlight major findings of the work carried out in this thesis and provide suggestions for further research in this area. Unit commitment and dispatch is very important aspect of power system operation and control. Almost in all power systems, major share is from coal based power plants in power generation. However, gas and hydro plants play a very important role in reducing the overall cost of power generation. Due to awareness for clean air, most of the power plants are using pollution control equipments to reduce the pollutants emitted by them. Attempts are also made to coordinate the generating units so as to control the emission. Dynamic Programming(DP) technique is used by many researchers for optimal unit commitment. In this thesis, DP is used to find optimal unit commitment of mix system along with emission control. The sailent features of the thesis include the development of

- A new method to represent a thermal system by equivalent cost function along with expression to allocate generation share on each unit.
- A new method for economic generation scheduling of thermal system.
- An algorithm for hydrothermal scheduling, thermal-gas and in general mix generation system.
- Methods to obtain optimal order of combination of units along with range of operation and an algorithm for combination order of multifuel units.
- Algorithm for economic and environment dispatch.
- A generalized approach to obtain optimal unit commitment schedule of thermal and mix generation system without and with emission constraint.

7.2 Summary of Important Findings.

In chapter 2, Recursive Technique of Dynamic Programming is used to obtain equivalent cost function of thermal generating units. The formulation is very simple and in the process of formulation of equivalent cost function, expression for generation allocation is also formed. Due to possible violation of bounds by a unit, plant cost function is required to be corrected for which a method is developed. An equivalent cost function can be formed to represent a group of units, a plant comprising number of units or an area comprising number of plants. An algorithm is also developed to estimate generation scheduling for a single area dispatch with and without transmission losses.

Further, a successful attempt is made to estimate interchange evaluation among areas of a multiarea system. The proposed technique is also being applied to estimate generation scheduling for multifuel units. The work is tested by solving illustrative examples and it is revealed that

(1) Approach for forming equivalent cost function is correct and gives accurate results.

(2) Generation allocation by proposed method gives accurate results.

(3) On violation of bounds by a unit, plant functions are corrected. Using this corrected function, total cost and generation scheduling is found to be accurate.

(4) Conventionally, in a system comprising of plants with multiple generating units, scheduling is calculated using penalty factors. Penalty factors are used as many times as number of units, whereas in the proposed method, the number of times penalty factors are used is limited to number of plants.

(5) Allocation of generation on each unit of a plant can be easily calculated from plant generation. In conventional method of Lagrangian multiplier, once a unit violates a bound, it is assigned the bound value and deleted from list for further calculation (except for calculation of transmission losses), whereas in our method it is shown that having corrected the cost function, plant generation can be calculated without deleting that unit from the list.

(6) Representation of a system by an equivalent cost function is useful in interchange evaluation. The results obtained for a sample example matches with the results published by others.

(7) The method can be used for interchange evaluation in a multiarea and gives accurate results.

(8) The methodology developed is also useful for estimating generation allocation for units with multiple fuels. The methods proposed by others are based on Lagrangian multiplier and the same is different for different demands, whereas in our method,

a look up table is formed, which provides information regarding units and their fuels status for various load ranges. Hence for any load, observing the appropriate range, units' fuel can be easily decided and generation scheduling can be estimated as usual.

Chapter 3, is an attempt to estimate generation scheduling of a mix-generation system. First, a simple technique is developed for hydro-thermal scheduling using dispatch algorithm developed in Chapter 2. Further, using equivalent cost function criteria, a critical load level is calculated above which hydrothermal coordination will be economical. The same technique is then extended for thermal gas coordination and finally the problem is generalized as a scheduling problem of mix-generation system. All the above developments reveal following observations.

(1) For fixed head hydro plants having quadratic discharge function, hydro-thermal dispatch can be estimated.

(2) The cost of hydro-thermal scheduling using hydro plants at appropriate hours is less than its counterpart.

(3) The procedure is also useful for thermal gas coordination.

(4) Lastly, a successful attempt is made to obtain a solution of scheduling.

In chapter 4, an attempt is made to develop optimal order of combination of units eliminating the need to use discrete step size to form optimal order of combination of units along with the range of operation. Using equivalent cost function criteria, four methods are developed to form a table to represent sequential optimal order of units, optimal order combination of units and corresponding range of operation. The methods are direct and fast. These four methods are:

(1) Average Full Load Cost(AFLC)

(2) Direct Forword Tracking Approach

(3) Unit ordering by AFLC and Heuristic Forword Tracking Approach.

(4) Unit ordering by Back Tracking.

A Three step strategy is adopted to form unit commitment table. Next a successful attempt is made to find optimal order of combination of units and unit commitment table using method No.3 for a system having units of multiple fuel type. Result of the several examples reveal following observations.

(1) It is possible to form optimal order of combination of units by the methods stated above.

(2) Methods are direct, fast and the process of fixing step size is eliminated.

(3) Method of AFLC is not always optimal.

(4) Rest of the Methods give accurate results.

In Chapter 5, a simple approach is proposed for economic and environmental dispatch using basic dispatch algorithm. Algorithm incorporates 'tradeoff' so as to maintain a specified emission level at minimum cost. The algorithm solves this problems in three steps.

(1) Economic Dispatch

(2) Environmental Dispatch

(3) Economic and Environmental Dispatch.

Unlike reports of other researchers, the problem of emission constrained dispatch is treated as localized problem and at every plant, a specified NOx level is assigned. The developed algorithm, for any load, restricts generation of a plant as dictated by specified NOx level and this also helps, if necessary to maintain NOx level on any plant applying trade off strategy. From solution of these examples following observations are worth noting.

(1) The method developed is simple and gives satisfactory results. The cost of economic dispatch is least and NOx level is higher than the expected value. However, environmental dispatch costs more but NOx level is lower than the specified level. Hence trade off technique is applied and as expected NOx level is maintained at cost lesser than the latter.

(2) It is possible that a particular plant may emit NOx higher than the specified level above a critical load. Then, the capacity of the plant can be reduced to the critical load. Above this critical value, the plant will emit NOx more than spacified limit. Thus, a plant can be derated easily to a safe NOx level. This may require balance load to be shared by other plants operating still within safe NOx level.

In Chapter 6, an attempt is made to obtain unit commitment schedule of a thermal and mix system. The procedure is based upon the developments proposed in preceding Chapters. For each system, two types of problems are solved: (1) the unit commitment and schedule and (2) the emission constrained unit commitment and schedule. In latter problems, Patton's security function is used to ensure the reliability of thermal units. Special feature of this is emission constrained unit commitment. The procedure initiates with formation of optimal combination order based on economical aspects. Each combination order is assigned 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 observations 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 to include 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 decomposition type. The main problem consisting of number of units is decmoposed into small problems or subproblems. The subproblems are formed by grouping of units called plants (which is a reality). Each subproblem is solved independently and solution of these problems is again used to link with the main problem and finally 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.

7.3 Scope for Further Research

As a consequence of developments in this thesis, the following aspects are suggested for further research.

(1) In Chapter 2, it is shown that a system can be represented by its equivalent cost function. This aspect can be used to develop technique for generation scheduling including transmissionn losses. Since an area can be represented by an equivalent cost function, it is possible to develop a method for multiarea dispatch using Diakoptics[129]. The method developed for generation scheduling for multifuel units can be further modified by backward dynamic programming.

(2) In Chapter 3, a simple method is developed for Hydrothermal dispatch for fixed head with scheduling horizon of 24 hours. If horizon can be increased to 168 hours, with deterministic head for each day, then developing a factor which may give corrected head for next day, the scheduling can be estimated for a week.

(3) In Chapter 4, using backword dynamic programming, a method can be developed for obtaining optimal combination order of units with multiple fuel options. Further, assessment of security can be easily applied for three step unit commitment method.

(4) Many researchers frame the unit commitment problem which includes aspects such as startup cost, shutdown cost, minimum up-time, minimum down-time and reserve margin and emission constraints. The proposed technique is flexible to include these aspects also. Hence, further attempt may be made in this direction. Moreover, in addition to above sorts of generating units, units with multiple fuel options may also be included in this method. In the proposed method, range of operation of combination orders were optimally corrected due to one constraint of NOx. It is possible to extend this concept by including two constraints such as NOx and SOx. Based on formulation developed in Chapter 2, it is possible to develop a generalized multiarea unit commitment method with all types of sources and with multiemission constraints. Further attempt may be directed to include all practical problems and constraints such as maintenance of voltage control, voltage stability, emission control over an area.