Ain Shams University

Faculty Of Engineering

OPTIMAL SCHEDULING OF THERMAL GENERATION IN ELECTRIC POWER SYSTEMS

BY

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A Thesis

Submitted in partial fulfillment for the requirements of the Degree of Master in Electrical Engineering

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Cairo - 1988

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بسم الله الرحمن الرحيم

<u>STATEMENT</u>

This dissertation is submitted to Ain Shams University for the degree of master in Electrical Engineering.

The work included in this thesis was carried out by the author in the Department of Electrical Power and Machines, Ain Shams University, from 12 / 12 / 1983 - / / 1988.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ACKNOWLEDGEMENTS

My deepest gratitude goes to Prof. M. A. EL-SHARKAWY for his supervision, many valuable suggestions, continuous encouragement and constructive discussions throughout the present work.

Great appreciation is due to Dr. MOHAMED ABDEL-AAL who suggested the topic of this research, for his fruitful discussions and guidance during the course of the work presented in this thesis.

Thanks also for the head of electrical power and machines department - Ain Shames University, Prof. Dr. Ahmed M. El-Arabaty for all facilities he made.

Last but not least, I wish, to extend my very warm gratitude to my parents and wife, who made it possible for me to complete this work.

SUMMARY

Saving fuel cost is of utmost importance to the Egyptian economy.

This thesis is concerned with short-term optimal scheduling of thermal generation in electric power systems to achieve minimum operating cost including both running and start-up costs satisfying a desired level of system security.

The thesis provides two different approaches for mathematical modeling of thermal generation in economic operation of power systems. The first (original) model deals with the power system as composed of individual units, and the second considers the power system as consisting of equivalent generating stations.

Two computer programs are developed based on the two different models for solving the unit commitment and optimal scheduling problems.

The optimization problem is solved using the dynamic programming technique.

The considered cost function is of the 2 nd and 3 rd orders.

Spinning reserve is evaluated using a security function based on a probabilistic approach.

The start-up cost is taken as function of the unit parameters in the exponential form.

The developed programs are applied for a regional system of the Egyptian Unified Power System.

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LIST OF ABBREVIATIONS AND SELECTED SYMBOLS

DP : Dynamic programming.

IHR : Incremental heat rate (MCAL/MWH)

MTIL : Maximum tolerable insecurity level.

UCT : Unit commitment table.

N : Number of generating units.

P_D : Load demand.

S : Security function.

ΔP_s : Load power step used in load sharing among generating units in the DP algorithm.

ΔP_u : Power step (MW), used in unit commitment calculations.

λ : Lagrangian multiplier.

α : Thermal time constant of unit.

CHAPTER (1)

INTRODUCTION AND LITERATURE REVIEW

1-1 General:

The efficient and optimum operation and planning of electric power generation systems have always occupied an important position in the electric power industry [1-43]. The economic operation problem in electric power systems involves the scheduling of both thermal and hydro generating units to minimize the cost of supplying the power requirements of the system over a specified period under specified system constraints.

The present study concerns only with the thermal generation scheduling, which can be considered as the major part of the whole scheduling problem of hydrothermal power systems, because the problem of minimizing operational cost of a hydrothermal system can be simplified essentially to only the problem of minimizing the fuel cost for thermal plants under the constraints of the water available for hydro-generation in the given period of time.

Meanwhile, the decomposition technique is widely used for solving the hydrothemal scheduling problem. In such method the system is decomposed into :

(i) thermal plants and electrical network, as a separate subsystem, and

(ii) hydro subsystems, as another subsystem.

The solution of each subsystem is computed separately, and then all solution for different subsystems are combined and improved by successive iterations, to get the optimal scheduling for the entire system [10-13].

In this thesis, the problem of thermal generating units scheduling has been studied in two stages :

(i) Economic dispatch ,and

(ii) Unit commitment problem.

Then incorporation of the two stages is carried out to obtain the integrated solution of the entire problem.

1-2 Economic Dispatch Computation

Optimal dispatch is a computational process whereby the total generation required is allocated among the available generating units so that the imposed constraints are satisfied and the energy requirements in terms of BTU/HR or LE/HR are minimized.

Economic dispatch problem dates back to the early 1920's or even earlier. Prior to this year various methods were in use such as [1,25]:

(1) The base load method, where the most efficient unit is loaded to its maximum capability, then the second most efficient unit is loaded, etc....,

(2) Best point loading method, where units are successively loaded to their lowest heat rate point beginning with the most efficient unit, and working down to the least efficient unit, etc.....

It was recognized as early as 1930, that the equal incremental method can lead to the most economic results [14].

The idea of incremental loading of the early pioneers is that the next increment in load should be picked up by the unit whose incremental cost was the lowest. It was recognized that the net effect would be an equalizing of incremental costs. A formal proof that equal incremental loading results in a minimum (BTU/HR) input was given by Steiberg and Smith in 1934, [15]. They have proved that the total generation cost from a two unit system having negligible transmission loss will be minimum only if :

$$\frac{dF1}{dP1} = \frac{dF2}{dP2} \qquad (1-1)$$

where P1, P2 ; F1, F2 and $\frac{dF1}{dP1}$, $\frac{dF2}{dP2}$ are the output power, the generation cost and the incremental cost for units 1 and 2 respectively.

In such methods, generator models are considered and the effect of transmission network is neglected.

The loss formula was primarily used in the construction of average charts through the 1940's. Then, Kron's work reported in a series of four papers [15,17]; gave the fundamental treatment of network losses in a single area [16], and losses in interconnected areas [17].

Kirchmayer and Stagg [18] also did a big effort to work out a practical method for applying Kron's theory. This effort has resulted also in improving the loss formula calculation procedures.

Kirchmayer and Stagg also teamed up in deriving -on the basis of Lagrangian Tech.- what is now known as the classic coordination equations [19] and used to this day.

$$\frac{dF_i}{dP_i} + \lambda \frac{\partial P_L}{\partial P_i} = \lambda \quad , \; i = 1,2,....n \qquad (1-2)$$

Where:

F_i is the fuel cost function for the unit no. i

P_i is the output power from the unit no. i

P_L represents the total transmission losses.

El-Abiad and others, developed an algorithm for real power and voltage magnitude (i.e. reactive power) dispatch based on the general formulation of the economic dispatch problem using Lagrange multipliers approach [20]. A feasible