ON LOAD FLOW AND ECONOMIC LOAD DISPATCH IN INTEGRATED POWER SYSTEMS

by

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ELECTRICAL ENGINEERING DEPARTMENT

Submitted

in fulfilment of the requirements of the

Degree of Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

NOVEMBER, 1979

Dedicated to

my parents

CERTIFICATE

Certified that the research work 'On Load Flow And Economic Load Dispatch In Integrated Power Systems' by P.R. Bijwe, has been carried out under my supervision at the Indian Institute of Technology, Delhi and that this work has not been submitted elsewhere for the award of a degree.

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ACKNOWLEDGEMENTS

The work described in this thesis was carried out under the supervision of Dr. J. Nanda, Professor in the Department of Electrical Engineering, Indian Institute of Technology, Delhi. I have great pleasure in expressing my gratitude to Professor Nanda for his constant encouragement, stimulating discussions and valuable suggestions during the course of this work.

I also wish to thank Dr. D.P.Kothari, Assistant Professor in the Centre of Energy Studies, I.I.T. Delhi for his kind help during the last phase of this work. My thanks are also due to Dr.K.S.P.Rao, Assistant Professor in the Centre of Energy Studies, I.I.T. Delhi for many discussions I had with him.

I am grateful to the Head, Department of Electrical Engineering and Head, Centre of Energy Studies, I.I.T. Delhi for providing the facilities for carrying out the research work.

I wish to thank the Staff of Computer Centre, I.I.T. Delhi for the facilities provided for digital computation.

I would also like to thank all my colleges who have contributed directly or indirectly during the course of this work.

Finally, I am grateful to my parents and wife for their understanding and constant encouragement during the course of this work.

(P.R.Bijwe)

November, 1979

A B S T R A C T

Load flow is the solution for the static operating condition of the power system. It is the most frequently performed power system study on digital computers. Load flow calculations are required for power system planning, operational planning and actual planning/control. Due to the tremendous importance of the problem, there has been a continual interest in developing better and better solution algorithms.

The load flow methods are compared with each other by the various criteria of goodness such as, low storage, high speed, reliability, ease of programming etc. Storage is a perennial problem for many users. With the advent of small fast computers, storage is much more a limiting factor than speed. An attempt has therefore been made to develop a new piecewise load flow algorithm requiring the storage at par with that of Gauss-Seidel approach and embedding the sensitivity information that can be used for economic load dispatch aspects. Salient features of the algorithm include (i) use of Newton-Raphson procedure with P-δ and Q-V decoupling, (ii) formation of several smaller jacobians and solution of the corresponding sets of equations in succession instead of formation of a full jacobian and the simultaneous solution of the equations.

Given a load demand in a power system, there are various ways in which the demand can be met by allocating

the generations to various power plants. However, out of all these generation schedules, there is only one schedule which results in a minimum cost of generation. The problem of obtaining the most economical generation schedule is known as economic load dispatch.

Though Gauss-Seidel method has minimum storage requirements it is rarely used for economic load dispatch since it is devoid of any sensitivity information. The Newton based methods on the other hand provide sensitivity information but are too much storage consuming particularly for very large systems. Thus with the present state of art in load flow, there is no low storage algorithm which can be used for economic dispatch. In order to achieve this objective, a piecewise method has been developed for evaluating the penalty factors which is computationally fast and requires very little additional storage over and above the storage required by the earlier mentioned new piecewise load flow algorithm. Economic load dispatch results for a 25 Bus sample test system have been obtained which compare well with those obtained by earlier researchers.

Transmission loss formula represents the transmission loss in terms of a set of predetermined coefficients and the plant generations. The reason for its wide appeal is that it provides a very fast and convenient means of evaluating incremental transmission losses without recourse to direct network solutions. Kirchmayer and Stagg have done pioneering work in developing computational procedures for the evaluation of loss coefficients and also in the development of classic coordination equations. Because of the assumptions and considerable computational efforts involved in evaluating the usual loss formula coefficients there has been a continual interest in seeking methods which are faster and more accurate. Most of the recent methods require a number of ac power flows for the evaluation of these coefficients. In the present work an attempt has been made to develop a new transmission loss formula which dispenses with the assumptions involved in the earlier methods. All these coefficients of the new formula can be generated through a single Newton-Raphson load flow-solution irrespective of the system size. This introduces the possibility of updating the loss formula on-line with the changes in load pattern and the transmission network. The new transmission loss formula has been used for economic load dispatch for two sample systems and the results are found to compare well with those obtained with other methods.

The cost associated with hydrogeneration is negligible compared to that of the thermal generation. Hence, it is possible to plan the drawdowns for power generation from the reservoirs in such a way that the cumulative cost of thermal generation over the entire scheduling interval is minimized without violating the constraints on the hydro and the thermal-electric subsystems.

Kirchmayer[1] extended his famous hydro-thermal coordination equations to the hydro-thermal scheduling problem using variational approach. The technique is quite simple and easy to implement. It cannot, however, treat all the constraints imposed by hydro and thermal-electric subsystems. Dynamic Programming, Incremental Dynamic Programming, Discrete and Continuous Maximum Principle, Nonlinear Programming have also been applied for the solution of this problem. Most of these algorithms require considerable computational storage and time to solve a problem of realistic size. Rao _et al_[2] have developed an algorithm for hydro-thermal scheduling based on 'Method of Local Variations'. The difficulty with their algorithm is that a large number of thermal optimizations are required in the solution process. Thus this algorithm is not very attractive as far as solution speed is concerned. In order to overcome this problem an algorithm based on the 'Principle of Progressive Optimality', has been developed. The salient feature of the algorithm is an iterative procedure involving a series of two stage one variable optimization problems with weighted output as a performance index, such that the total fuel cost decreases monotonically from iteration to iteration, till a satisfactory convergence to the optimal trajectory is obtained. Furthermore, based on some realistic assumptions a scheme has been suggested by which the weighting factors used in the optimization can be updated directly without recourse to thermal optimizations during iterative procedure. This makes the algorithm extremely fast rendering it suitable for on-line applications.

A two hydro, two thermal sample test system has been studied to demonstrate the applicability of the Progressive Optimality algorithm (POA). Results obtained confirm the fact that the new algorithm is much more faster than that based on 'Method of Local Variations'

An extremely important problem in hydro-thermal scheduling is the hydrodynamics introduced by cascaded reservoirs with water transport time delays. Dynamic Programming Discrete Maximum Principle and some nonlinear programming techniques have been used in the past for the solution of this problem. As mentioned earlier most of these techniques require considerable computer storage and time for a realistic size problem. Rao[3] has used an algorithm based on Method of Local Variations for the solution of this problem. However, Rao's algorithm becomes still less attractive for the problem of this nature because of the significant increase in the number of thermal optimizations per iteration as compared to that involved in the problems without time delay. Hence, an algorithm based on Progressive Optimality Algorithm has been developed to explore its suitability and effectiveness for the problem under consideration. Hydro-thermal scheduling results for a sample two hydro (cascade connected) and two thermal (5 Bus) system have been obtained using POA. Investigations reveal that the application of POA to hydro-thermal scheduling with cascaded reservoirs is devoid of the shortcomings in the MLV algorithm and appears to be quite promising for practical applications.

In order to utilize the capacity of the pumped storage plant in a most efficient manner, it is necessary to perform an optimization study for the system which determines the optimal pumping and generating schedules for a pumped storage plant. Some work[2] has been reported in the literature regarding the solution of such a problem. The need for an efficient algorithm, however, still remains. In view of this, an attempt has been made to investigate the effectiveness of POA to pumped storage scheduling problems. The technique has been applied to a sample two hydro, two thermal (5 Bus) system and the analysis reveals the potential application of the algorithm to practical systems.

In most of the published work on the optimal hydro-thermal scheduling problem, it has been assumed that the water inflows and load demands on the power system are known with complete certainty. The assumption may be justified for a short range problem but, for a long range problem this is very much unrealistic. Some work has been reported in the past, dealing with such a stochastic optimization problem. There is, however, a need for an efficient algorithm for solving such problem, requiring minimum computer storage and time. Keeping this in view, the author has tried to explore the suitability and effectiveness of the application of the POA to stochastic hydrothermal scheduling problems. Computer results for a sample two hydro, two thermal system have been obtained.

TABLE OF CONTENTS