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MY PARENTS & TEACHERS

DIGITAL SOLUTION OF LOAD-FLOW
OPTIMAL LOAD-FLOW AND STATIC STATE ESTIMATION
PROBLEMS IN ILL-CONDITIONED POWER SYSTEMS

BY
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CERTIFICATE

This is to certify that the thesis entitled, "Digital Solution of Load-flow Optimal Load-flow and Static State Estimation Problems in Ill-conditioned Power Systems", which is being submitted by Mr. G.S.S.S.K. Durga Prasad for the award of the Degree of Doctor of Philosophy of the Indian Institute of Technology, New Delhi, is a bonafide record of research work carried out by him over the last three years under my guidance and supervision.

The candidate has fulfilled the requirements of all the regulations relating to the degree. The results obtained in the thesis have not been submitted to any other University or Institute for the award of a degree or diploma.

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ABSTRACT

This thesis presents application of mathematician K.M.Brown's method to the solution of load-flow, optimal load-flow and static state estimation problems. The method is particularly effective for solution of ill-conditioned systems of nonlinear algebraic equations. It is a variation of Newton's method incorporating Gaussian elimination in such a way that the most recent information is always used at each step of the algorithm, similar to what is done in the Gauss-Seidel process. The iteration converges locally and the convergence is quadratic in nature. A general discussion of ill-conditioning of a system of algebraic equations is given. It is also shown by fixed-point formulation that the proposed method falls in the general category of successive approximation methods. Digital computer solutions by the proposed Brown's method are given for several ill-conditioned power systems for which the standard load-flow methods failed to converge. Even if much progress has been made in load-flow analysis, there are situations which cause difficulties in obtaining solutions with some of the standard methods. Some of the causes of instability and divergence in load-flow solution methods are

- (a) the position of the reference-slack bus,
- (b) the choice of acceleration factors,
- (c) the existence of negative line reactance,

- (d) certain types of radial systems, and
- (e) a large ratio of long-to-short line reactance for lines terminating in the same bus.

Networks having the above features are known as ill-conditioned systems and are described by a system of nonlinear algebraic equations. The solutions of these equations are very sensitive to small changes in specified parameters such as bus data. In other words, small changes in parameter produce a large change in the solution.

A new algorithm is presented in this thesis for the load-flow solution of ill-conditioned power systems using Brown's method and the nodal admittance matrix. In Brown's method, each equation is expanded in approximate Taylor's series; however, the most recent information available is immediately used in the construction of the next function argument, similar to the procedure in the Gauss-Seidel process for the solution of sets of nonlinear equations. This contrasts sharply with Newton's method in which all equations are treated simultaneously. It has been proved that Brown's method is not equivalent to Newton's method. Digital computer results of the proposed load-flow are presented

for several ill-conditioned power systems, for which the standard load-flow methods, namely, Gauss-Seidel, Newton's, Fletcher-Powell and Fast Decoupled algorithms failed to converge with usual flat start. Although the Brameller and Denmead method works for ill-conditioned problems, it shows poor convergence. A comparison of this method with the standard load-flow methods is also presented for the well-conditioned AEP 14, 30 and 57 bus systems.

The optimal real power flow has been solved with approximate loss formulas by several authors. Approximate methods also exist for the optimal reactive power flow. Recently, attempts have been made to solve the optimal real and reactive power flow exactly. The general problem of optimal load-flow subject to equality and inequality constraints were formulated by Dommel and Tinney using the Lagrangian multipliers method and Newton-Raphson load-flow. Later, Sasson applied the Fletcher-Powell algorithm to the solution of load-flow and optimal load-flow problems with Zangwill's formulation. However, these well-known methods for optimal load-flow do not work for the ill-conditioned power systems. It is shown in this thesis that the application of Brown's algorithm to the set of necessary conditions for a minimum of the scalar objective function subject to the equality and inequality constraints results in faster convergence to the solution of the ill-conditioned power systems compared to the other methods. Digital computer results by the proposed Brown's optimal load-flow algorithm are presented for 13-bus ill-conditioned, 5- and 25- bus well-conditioned test

systems. Also the thesis presents a comparative assessment of convergence characteristics of all the three methods (Dommel and Tinney, Sasson, and Brown) for optimal load-flow solution of well-conditioned power systems. For the application of Brown's method, the optimal load-flow problem formulation is such that no move from one feasible solution to another is to be made for achieving the optimal solution unlike in Dommel and Tinney's gradient technique.

The static state estimation has also been solved by the proposed Brown's method. It is shown that the method converges faster than the Gauss-Newton method and Fletcher-Powell method for ill-conditioned systems. However, all these three methods are based on weighted least square formulation, that is, minimization of the sum of squared residuals (mismatches) of bus injections and the line flows.

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