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A FEW ALGORITHMS FOR ESTIMATION OF PARAMETERS OF A LARGE UNKNOWN POWER SYSTEM

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SUMMARY

Three algorithms for estimation of parameters of a large power system are reported. The algorithms developed respectively are for a five parameter and a four parameter dynamic models of the grid system with terminal voltage as the only measured output, and a five parameter model with the terminal voltage and frequency as measured outputs. It is observed that four parameter system with only terminal voltage output is computationally more efficient and at the same time provides reasonable estimates of the important parameters of the system.

INTRODUCTION

When the dynamic performance of one or a group of generators connected to a large power grid is studied, often computations are carried out considering the grid system as an infinite bus. This simple model of the power grid though simplifies calculations to a large extent, it cannot be used for more accurate studies. For good dynamic studies, all the machines in the power system including their control devices should be adequately represented. If instead of representing each and every machine dynamically, the entire grid system is replaced by one or a group of equivalent finite machines, a great deal of computational effort can be saved in a design study. Viewed from the generating unit of interest, the grid absorbs electrical energy and hence can be represented by a synchronous motor, parameters of which are to be determined. From measurement of some outputs of the system, these parameters can be estimated through a least squares error minimization technique.

FORMULATION OF THE PROBLEM

For small perturbations, the input - output relations of the local generator connected to the equivalent motor through an equivalent link can be expressed as

$$\dot{X} = A(\alpha)x + B(\alpha)u \qquad (1)$$

$$Y = C(\alpha)x \qquad (2)$$

where X, Y and u are the state, output and control vectors respectively. A, B, C are the coefficient matrices and α is the vector of unknown parameters of the synchronous motor. The value of α should be so chosen as to minimize

$$J = \tfrac{1}{2}\int_0^{t_f} e^T R e \quad dt \qquad (3)$$

where the error e is the difference between a reference (or measured) output and the model output of equation (2) for each estimated value of α. Expanding Y in a Taylor series and setting $\partial J/\partial\alpha = 0$, an algorithm for updating α is obtained from the set of algebraic relationships

$$D \cdot \Delta\alpha = N \qquad (4)$$

The recursion formula for updating α is

$$\alpha^i = \alpha^{i-1} + K \Delta \alpha \qquad (5)$$

where the acceleration factor matrix K is assumed to be diagonal.

ALGORITHMS & RESULTS

The estimation procedure is started by solving equation (1) and (2) for a given input with a nominal value of α to generate the reference output. If data from measurements are available, this step is not necessary. For any initial guess of α reasonably near the nominal values, the outputs and output gradients are calculated for the same input. Solution of the set of algebraic equations (4) gives the change in parameter values by which the estimates are to be updated. The matrices D and N are solved from a set of integro-differential equations involving the state and output gradients. The elements of the matrix K are dependent on the value of $\Delta\alpha$ as well as that of normalized cost index $\hat{J}$. The estimation process is discontinued when both $\Delta\alpha$ and $\hat{J}$ fall below some predetermined levels. A flowchart showing the different steps of the estimation process is given in Figure 1.

Algorithms for estimation of the unknown power system parameters were developed considering

1. A fifth order parameter model with terminal voltage as the only measured output. The equivalent synchronous motor is represented dynamically by a simplified third order model with the following parameters - the moment of inertia (H), damping coefficient (D), open circuit field time constant (T'_{do}), synchronous reactance (X) and transient reactance (X').

2. A fifth order parameter model with terminal voltage and frequency variation as measured outputs. Terminal voltage and frequency variation are given equal weights in the performance index.

3. A fourth order parameter model dropping the damping term from the estimation algorithm.

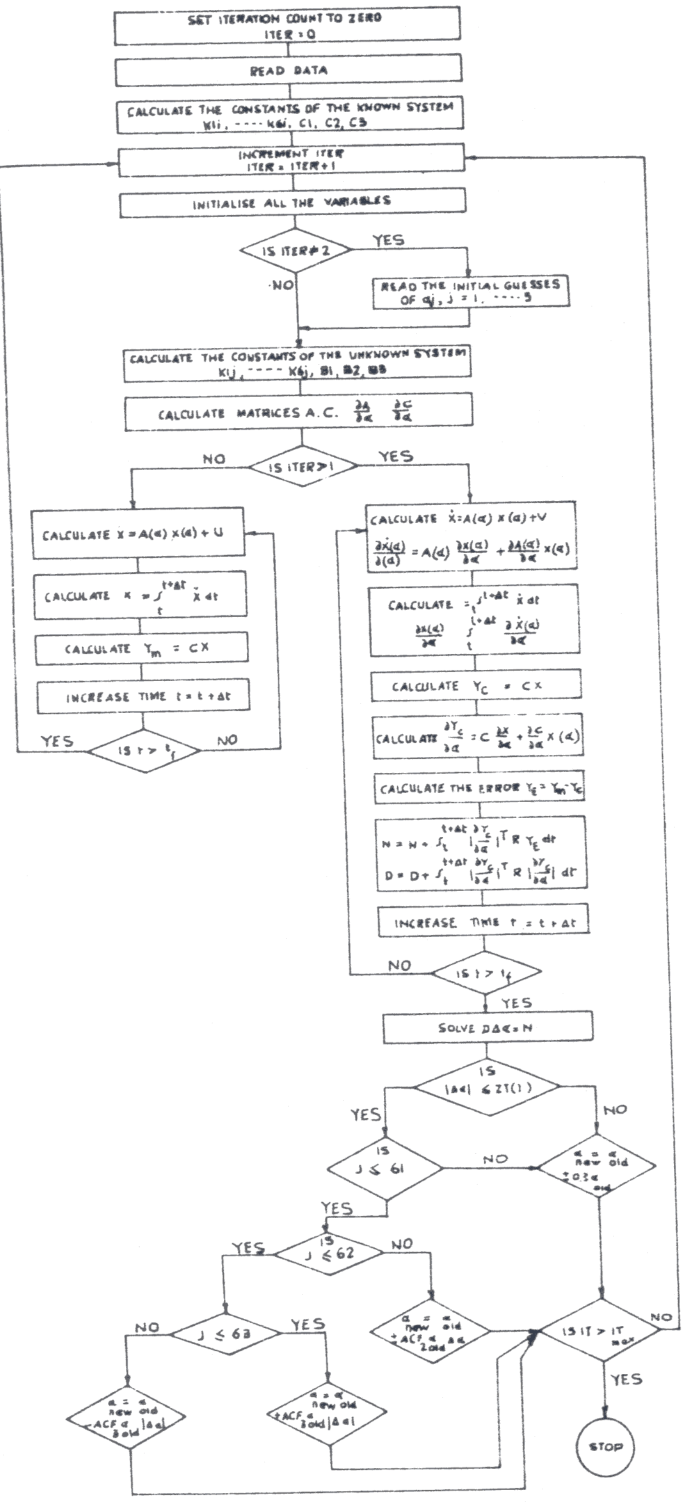

Figure 1. Flowchart for the parameter estimation algorithm.

The damping is kept constant at a small positive value. Estimation is performed on the basis of terminal voltage output records only.

The three algorithms were tested for a sample power system for a number of loading conditions at different power factors and several values of intertie impedances. Curve a in Figure 2 shows a sample plot of the norm of variation of the parameters against iteration number for an initial estimate of 2 times the nominal values of α. Curves b, c and d respectively show the variation of $\hat{J}$ for the three cases mentioned. It can be observed that estimation with both frequency and terminal voltage output records provide little better convergence near the minimum but the advantage so gained is not significant. With the four parameter model, convergence is little faster but the steady state error $\hat{J}$ is higher because the damping is kept constant at a small value different than that in case 1. The four major parameters can be reasonably estimated with less computation time in this case.

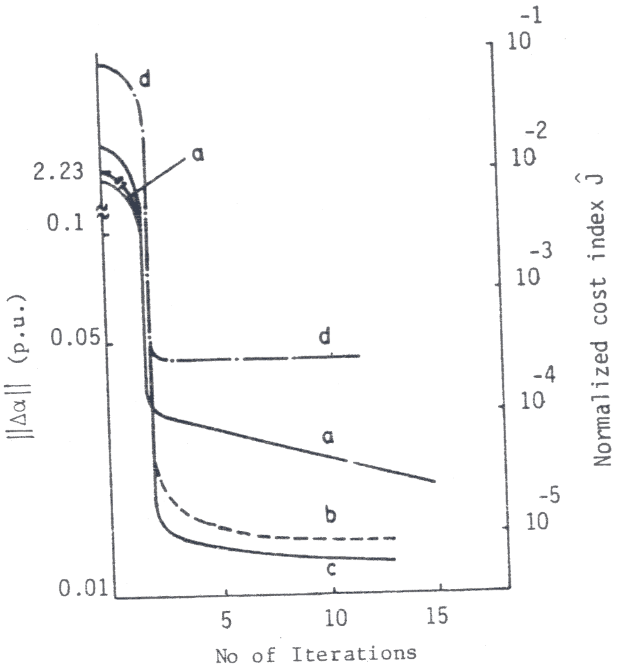

Figure 2. A sample plot of (a) $||\Delta\alpha||$ for the five parameter case (b) $\hat{J}$ with 5 parameter one output model (c) $\hat{J}$ with 5 parameter and two output model (d) $\hat{J}$ with 4 parameter model.

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