AN ABSTRACT OF THE THESIS OF

Barry Claude Dearborn for the Master of Science
(Name) (Degree)

in Electrical and Electronics Engineering presented on May 3 1972
(Major) (Date)

Title: PARAMETER SENSITIVITY ALGORITHM FOR A DIGITALLY-MODELLED DIRECT CURRENT EXCITATION SYSTEM

Abstract approved: Redacted for privacy
John F. Engle

An algorithm for computing the parameter sensitivities of an excitation system for a hydroelectric generation system is developed for model analysis in this thesis. The IEEE Type 1 excitation system representation, linked with a simplified alternator and voltage regulator equivalent, provide a closed-loop model for digital simulation. Parametric sensitivities are derived from computations upon the transient exciter field voltage response caused by a perturbation of the regulator reference voltage. The digital-analog simulator language, MIMIC, was utilized to implement the model. Exciter field voltage responses from models differing by variations in one parameter are converted to sensitivities by a FORTRAN program. Sensitivities, exciter field voltages and system parameters are listed as output data. A line printer plotting routine provides several types

of graphic representation for the sensitivity responses. A broad range of model specifications was executed to demonstrate the utility of these programs. Observations directly from the sensitivity results revealed the effects of parameter deviations upon the system's response. Program flexibility, providing the user with a wide range of options in both model specification and information output, received major emphasis throughout this study.

Parameter Sensitivity Algorithm for a Digitally-Modelled Direct Current Excitation System

by

Barry Claude Dearborn

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1972

APPROVED:

Redacted for privacy

Professor of Electrical and Electronic Engineering
in charge of major

Redacted for privacy

Head of Department of Electrical and Electronic Engineering

Redacted for privacy

Dean of Graduate School

Date thesis is presented May 3 1972

Typed by Cheryl E. Curb for Barry Claude Dearborn

ACKNOWLEDGEMENTS

The author desires to express deep appreciation to Professor John F. Engle of the Electrical and Electronic Engineering Department, Oregon State University, for the guidance provided and the timely review of this material.

Additionally, sincere gratitude is extended to the Oregon State Engineering Experimental Station and Bonneville Power Administration for establishing the communications and funding essential to this research.

A special "thanks" is deserved by the author's wife for her encouragement and typing efforts in behalf of this thesis.

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PARAMETER SENSITIVITY ALGORITHM FOR A DIGITALLY-MODELLED DIRECT CURRENT EXCITATION SYSTEM

I. INTRODUCTION

General Background

The transient analysis of power systems has been subjected to numerous analytical techniques since the evolution of large multi-machine networks. The classical problem of determining system stability limits has received wide attention. Parametric sensitivity analysis was first shown to be a useful tool for deriving stability margins by a Japanese team (1) in 1967. Sensitivity is defined as the variation in system response due exclusively to a change in value of a component parameter. Subsequent studies by other investigators (6, 7, 11) were also directed toward further identifying the effect of parameter variations upon system stability. System modelling was confined to simplified, linearized representations of the synchronous machines and their control devices.

With the advent of high speed digital computers, more detailed modelling with non-linear properties became feasible. In 1970, Leffler (9) investigated the effect of polyparametric variations, modelling a one-machine hydroelectric system including a voltage regulator and governor. The model was based on Park's equations for the transient response of a synchronous machine.

In the above cited studies, emphasis on detailed representation has been primarily confined to the synchronous machine. Equally important in transient analysis studies is the evaluation of the associated control system signals. Models for the simulation of voltage regulators, governors, turbines and exciters have been developed and utilized in various forms of complexity (3, 8). Although complex models of excitation systems have been developed, examination of their internal operation with a generation system has received little attention.

The following research will attempt to partially fill the information gap by presenting a detailed investigation of a particular hydroelectric excitation system associated with simplified representations of the alternator and voltage regulator. Specifically, the exciter model response to a small step perturbation of the regulator reference voltage will be subjected to parametric analysis. Changing the reference voltage simulates an adjustment in the alternator terminal voltage to accommodate a change in the voltage schedule. This action is not to be confused with the response caused by actual load changes or fault conditions.

Realm of Consideration

Many machine configurations subject to a control process are eligible for parameter analysis by methods of simulation. For this study, a particular segment of a hydroelectric generation system will be the sole object under investigation. More specifically, this system will be comprised of a direct current, rotating exciter, a three-phase alternator operating into an infinite bus and a voltage regulation mechanism. Detailed representation will be confined to the excitation system.

Simulation of the system's[1] performance will be accomplished by a digital program representing accepted configurations of the transfer functions.

The system, initially at steady-state (equilibrium operating conditions), will be upset by a step perturbation of the regulator's reference voltage. Because of the desirability of studying parameter sensitivity over a linear operating range, the magnitude of the disturbance will be limited to produce an exciter field voltage variation of less than 20 percent.

Evaluation of the simulated response will be considered significant to three decimal figures, in correlation with the system parameters and input quantities. Technical terms pertinent to the excitation system will convey the meanings set forth by the IEEE Power Generation Committee (5).

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[1]See Appendix I for definition of system used hereafter.

Sensitivity studies will be confined to the descriptive parameters of the exciter model. All other quantities necessary for numerical specification of a particular system will be designated through initial input. Additional programming to handle data processing and output display will be considered vital to this investigation.

Throughout the project, major emphasis will be placed on the development of techniques for the purpose of providing a software package to serve as a basis for further investigation in parameter analyses. Thus, program flexibility accompanied by descriptive documentation will receive considerable attention. Data from test simulations will only be analyzed to the extent of demonstrating the utility of the programs involved. Evaluation of the system by use of differential equations directly is beyond the scope of this research because of the difficulty in representing non-linear elements in the several simultaneous equations.

Objectives

The primary goal of the parametric sensitivity study is to develop a technique, employing digital computation, for determining the sensitivity versus time relationship for each of the six exciter parameters explicitly defined on page 18. Secondary significance will be assigned to a numerical sensitivity sample study enveloping a broad range of system specifications. The five objectives, briefly outlined below, capture the segmentation of this research.

1. Development of a digital program for satisfactorily simulating the field voltage response of the given excitation system to a step change in regulator reference voltage.

2. Utilizing the exciter field voltage response as the driver, develop a program to compute sensitivity and display all useful information.

3. Implementation of the above programs to compute sensitivities for a specific array of system specifications.

4. Demonstration of the utility of the parameter sensitivity programs by limited analysis of the results from objective three.

5. Observation of limitations and special features of the developed software.

II. GENERATION SYSTEM

Description

The physical system under consideration is typical of the hydrogeneration installations in the western United States that utilize General Electric equipment, In these sizeable generation units, the requirement of a large direct current source to provide alternator field potential is commonly achieved by using a large rotating, self-excited, direct current generator (the exciter). Control of the exciter output, which determines the alternator terminal voltage, is critical following an abrupt disturbance such as a fault, load or voltage schedule change. Therefore, these larger units use an exciter system with a capacity of over five kilowatts with a continuous, automatic error signal amplifier, the amplidyne. Such a system is depicted in Figure 1. Although this study is based on the equipment stated above, any other components represented by identical transfer functions can be substituted into the model for simulation. For modeling purposes, certain restrictions and clarifications are required in further defining the system.

Assumptions

Obtaining optimum control of the generation system output is the justification of a complex excitation system. Error signal feedback

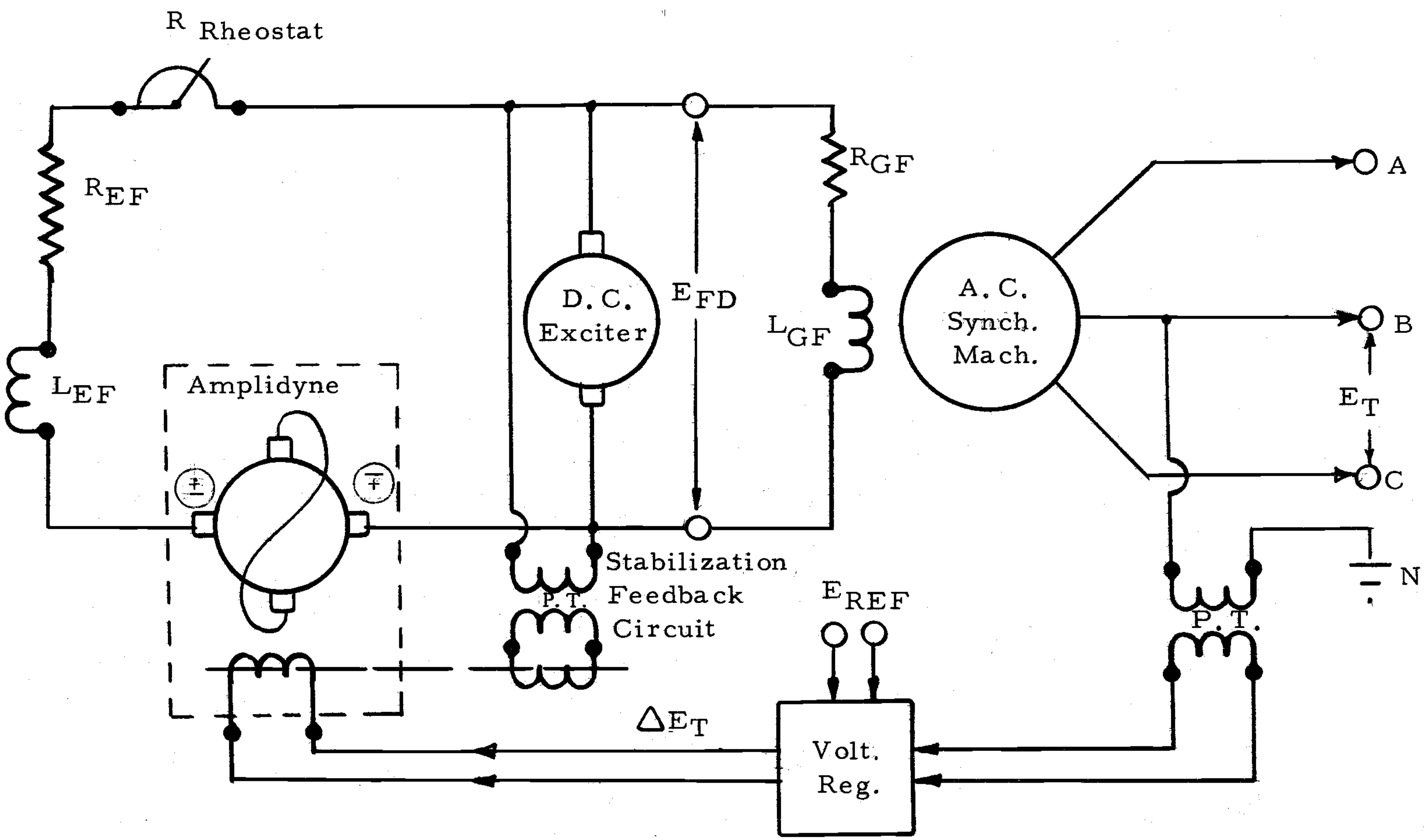

Figure 1. Generation system.

to the voltage regulator, an essential component of such control, is a function of the characteristics of the alternator and associated loading. Consequently, certain assumptions involved in a trade-off between modelling accuracy and avoidance of unjustified complexity are required. The assumptions below are commonly accepted as valid for adequate modelling (4).

1. Speed of the alternator remains unchanged throughout the test.
2. Alternator loading is constant for each test; more specifically, considered working through an external reactance into an infinite bus.
3. Regulator input filtering is considered negligible.
4. Only potential feedback derived from the alternator is used as a driver input to the voltage regulator.
5. The alternator's relationship to the excitation system serves mainly as a delay mechanism -- no initial gain.
6. No manual intervention with respect to adjustment of the exciter field rheostat will be considered.
7. Specified parameter values are accepted as being accurate, and assumed to remain constant.

III. SYSTEM MODEL

Excitation System

The definition of the objectives requires that the excitation system receives the greatest detailed attention. The single most important task, given definite characteristics of the equipment involved and their interconnections, is the implementation of a mathematical model to adequately duplicate the physical system's response. Results of considerable work in this field provide several models that can represent the excitation system for this study (4). In accordance with the assumptions previously enumerated, the IEEE Type 1 excitation system representation (Figure 2) satisfies the detailed requirements for adequate simulation results. By assumption three, block ① is eliminated. All quantities combining through summing point A can be considered external to the excitation system (treated later) by contributing the error signal caused by an alternator voltage variation from the reference voltage. Using block diagram algebra, blocks ④ and ⑤ in Figure 2 can be expanded as follows:

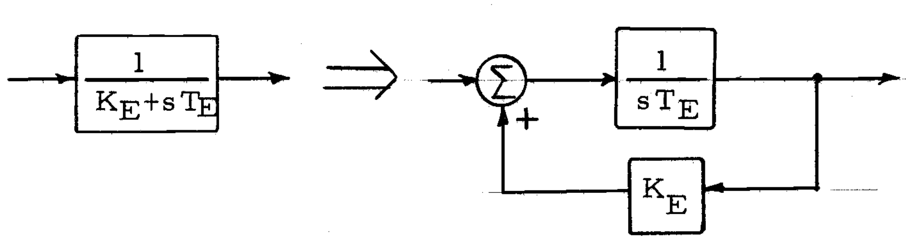

Figure 4. Expansion of block 4, Figure 2.

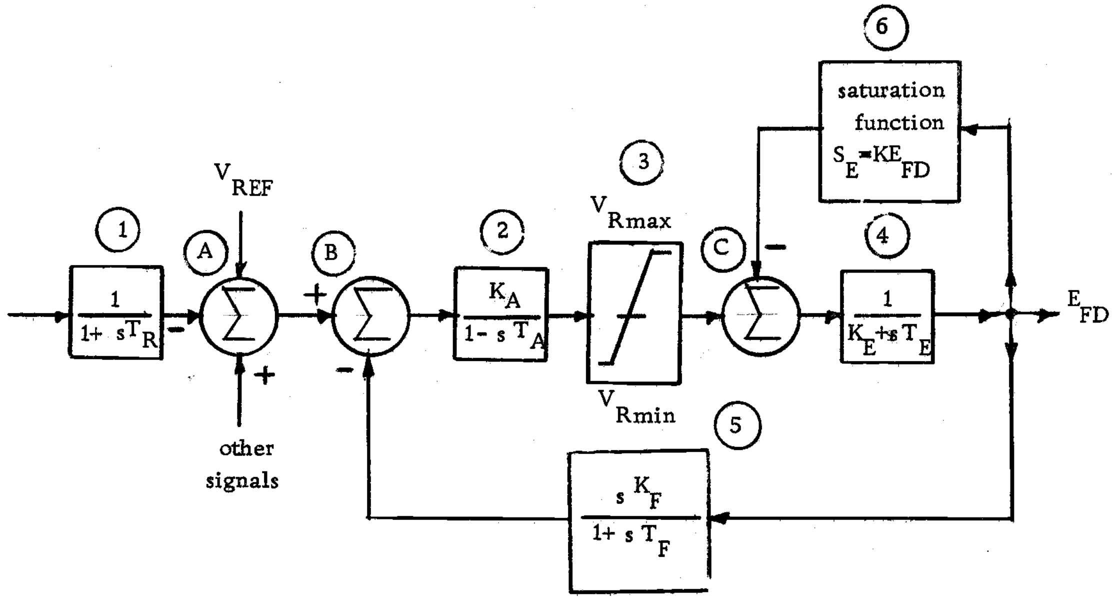

Figure 2. IEEE Type 1 excitation system representation.

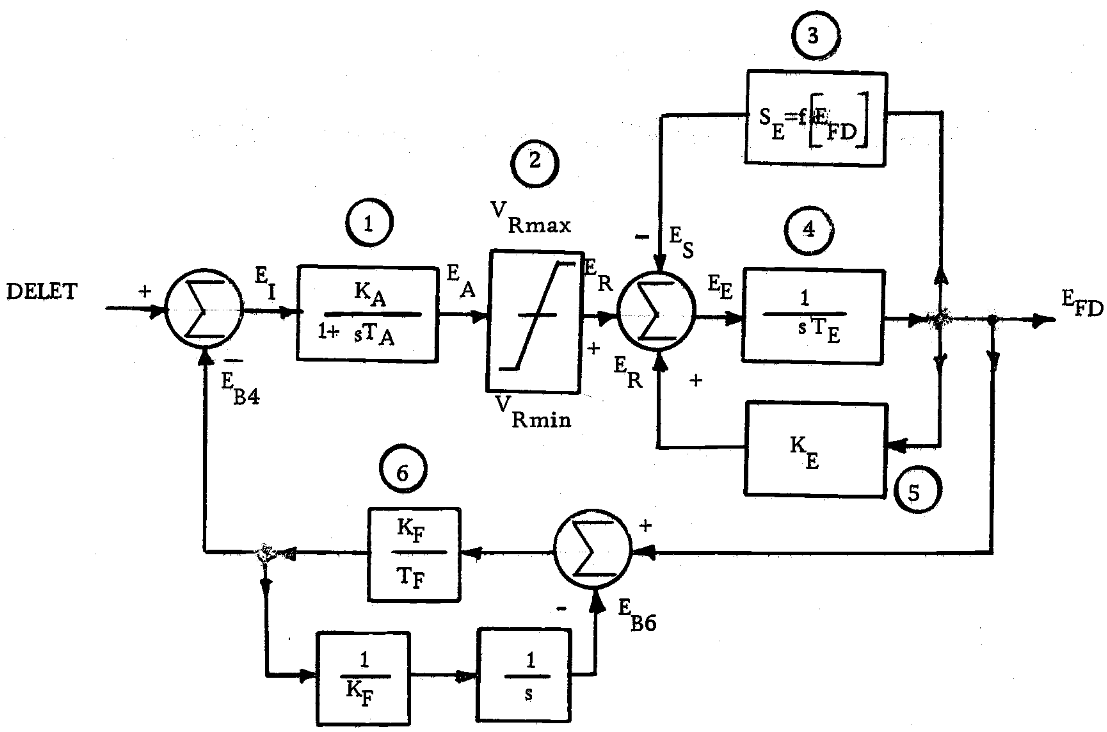

Figure 3. Equivalent exciter representation of IEEE Type 1 for modelling.

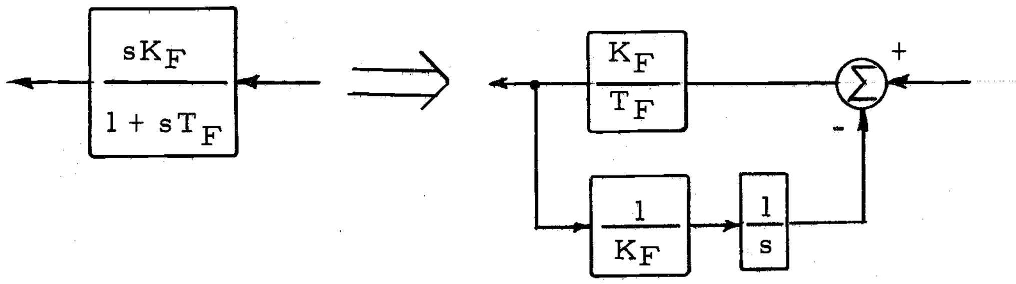

Figure 5. Replacement of a derivative with an integration scheme.

Figure 3 reflects the preceeding modifications applied to Figure 2 with the additional symbolization of all voltages.

Comprehensive explanation of the IEEE Type 1 exciter representation is well developed in the literature (4), but a brief summary relating the physical system with the model would appear appropriate.

With reference to Figure 2, the following relationships apply:

The amplidyne generator is a rapid-response, rotating amplifier, represented in blocks (2) and (3), either aiding or opposing the exciter field current to restore equilibrium to the alternator terminal voltage. Possessing, characteristically, a large gain and short time constant, the response caused by an abrupt perturbation within the system, must be limited within a defined 'normal' range to prevent possible field winding damage.

To further prevent 'overshoot' during a transient disturbance, a major damping loop (negative feedback) is provided through block (5). A non-zero exciter field voltage time derivative causes an error signal to be input to the amplidyne generator. The gain and time constants of this function are very important to system stability.

Block (4) represents the effect of the self-excited, direct current machine, neglecting saturation. When the field circuit resistance (rheostat plus field winding) is equal to that of the air-gap line, the machine acts as an integrator. Now considering field saturation effects, block (6), the steady-state operating point, is attained when the saturation voltage contribution (negative) is exactly equal to the self-excited voltage contribution, K_E times E_{FD} (2). The value of the field rheostat ($E_S \doteq E_K$ in Figure 3) is taken into account by this procedure.

Typical steady-state operation of the loaded exciter requires significantly more field current than operating at the same voltage on the air-gap line (Figure 6). A non-linear relationship exists between field voltage and field current because of the nature of magnetic saturation. To satisfactorily simulate the response of such an exciter, the saturation effect must be represented as a non-linear function of the field voltage, directed as negative feedback (see block (3), Figure 3). The form of the saturation function has not been agreed upon in the available literature (4), but exponential functions of the

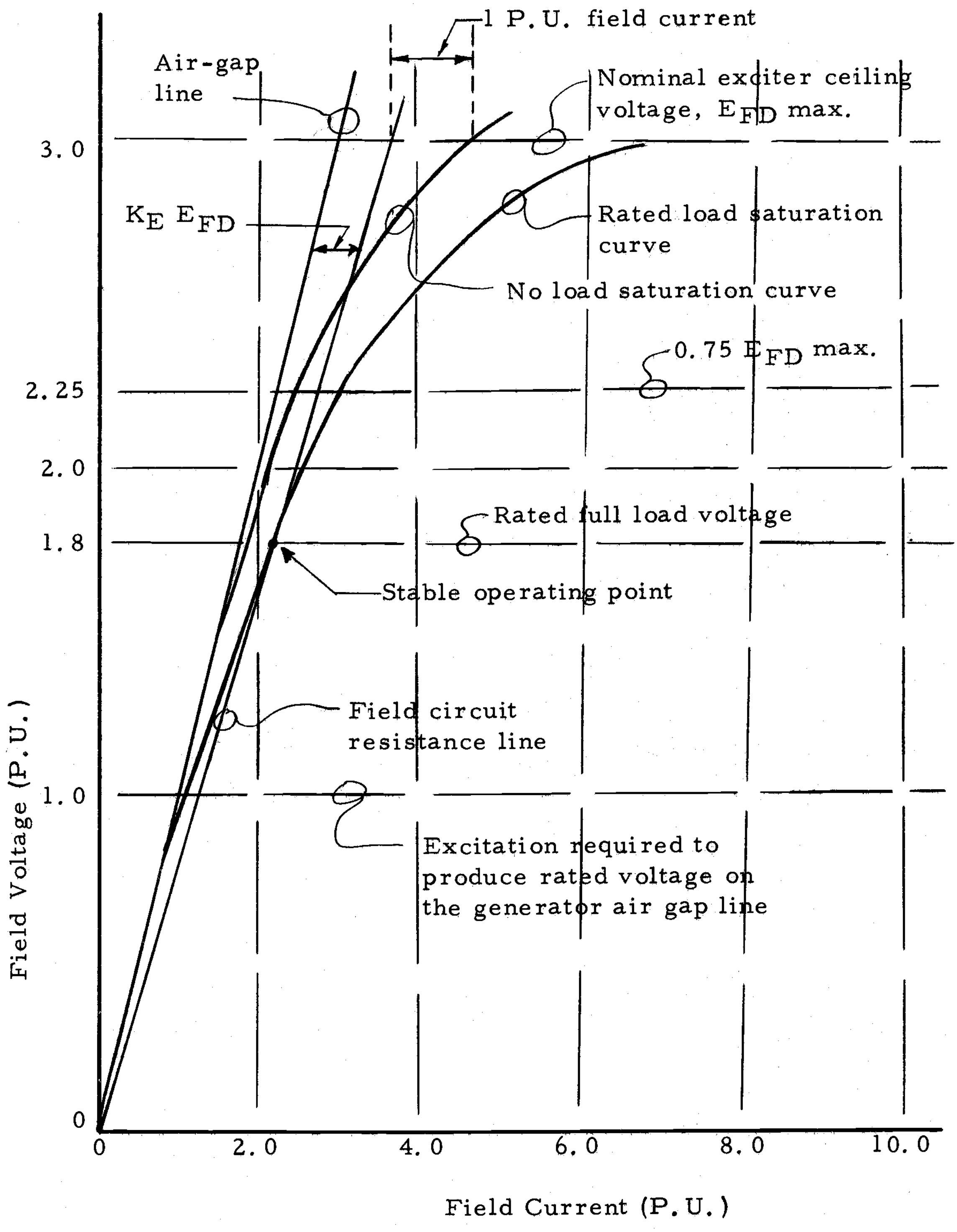

Figure 6. Exciter saturation characteristics.

form,

$$S_E = \frac{K e^{C E_{FD}}}{E_{FD}} \tag{3.1}$$

have been shown to give a reasonable approximation (8). The physical phenomenon of a residual voltage at zero field current, can be neglected because the field voltage fluctuation will be small, thus the non-excited state is not approached. Therefore, no appreciable error will be introduced by forcing the mathematical function to pass through the origin.

To accommodate this feature, the author has chosen to modify equation (3.1) to the form below:

$$S_E = K E_{FD} e^{CE_{FD}} \tag{3.2}$$

where: e is the Napierian base = 2.7183 (approx.)

C and K are constants to be determined.

Again, it should be emphasized that the above saturation function is valid only for positive values of field voltage and is particularly suitable for small field voltage variations; a requirement in sensitivity testing. Standard practice is to evaluate the constants, C and K, from values of the saturation function given at the two field voltage values, E_{FDmax} and 0.75 E_{FDmax} (see Appendix I).

Closed-Loop Generation System

The excitation system, a control mechanism for providing the required alternator field current, must be included within a closed-loop system. Meaningful simulation requires that the generation system provide a feedback signal from the alternator output. Transient behavior of the alternator is closely approximated by a synchronous machine operating into an infinite bus through the leakage reactance of the step-up transformer.

The alternator representation for transient analysis is illustrated in the one-line diagram below.

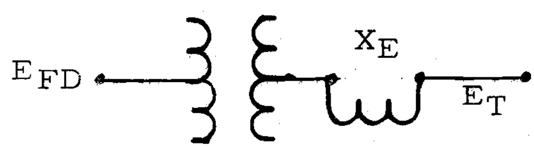

Figure 7

A transfer function relating terminal voltage to field voltage for the above diagram is:

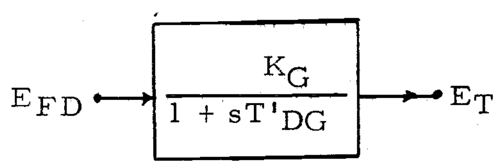

Figure 8

where: K_G is the gain relating the alternator terminal voltage to the exciter field voltage.

T'_{DG} is the transient time constant.

The transient time constant can be represented in terms of direct-axis reactances, leakage reactance and an open-circuit time constant.

$$T'_{DG} = T'_{do} \left[\frac{X'_d + X_E}{X_d + X_E} \right] \qquad (3.3)$$

where: T'_{do} is the open-circuit direct axis transient time constant.

X_d is the direct-axis armature (synchronous) reactance.

X'_d is the direct-axis transient reactance.

X_E is the armature leakage reactance.

The alternator gain term, K_G, is set to the value required to produce nameplate voltage at the terminals under steady-state conditions. Excitation correction is initiated by a deviation of the alternator terminal voltage from a pre-set reference voltage.

The block diagram below completes the structural description of this generation system.

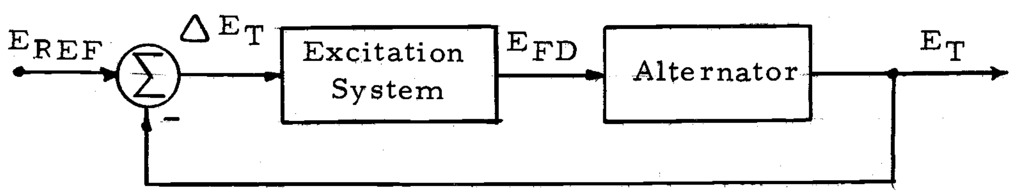

Figure 9

To study the effects of exciter parameter variations, the steady-state equilibrium of the above system must be disturbed. Simulation of the system response to a sudden terminal voltage error not initiated by causes external to the generation system (faults and load switching) is accomplished by a step change in the comparator reference voltage, E_{REF}. Now that the framework is developed for excitation system performance testing, specification of parameter values will be considered.

Specifications

Digital simulation of interconnected equipment, each with its own energy transfer characteristics, requires some method of relating electrical quantities. The definitions below describe a commonly-used per unit system (4).

One per unit alternator voltage - is the rated nameplate voltage.

One per unit exciter voltage - is the voltage required to produce rated terminal voltage on the alternator air-gap line.

One per unit exciter field current - is the current resulting from one per unit exciter voltage at steady state.

One per unit regulator voltage - is the voltage regulator upper limit, V_{Rmax}.

For simulation purposes, numerical parameter specifications and initial conditions are required. The six exciter parameters to be subjected to sensitivity testing are: K_A, T_A, T_E, S_E, K_F, and T_F (see Figure 3). Consultants from Bonneville Power Administration Engineering Division supplied nominal values for each of these parameters, closely approximating an actual operational system. Associated parameter ranges (4) and the supplied nominal values are given below.[2]

Table 1. Exciter parameter values.

Exciter Parameter	Range	Nominal Value
K_A	25 - 50	50
T_A	0.06 - 0.20	0.06
T_E	0.5	0.417
T_F	0.35 - 1.0	1.0
K_F	0.01 - 0.08	0.0667

The sixth parameter subject to study, the saturation function (S_E), can be defined from the supplied values of S_E for E_{FD} ceiling and $0.75E_{FD}$ ceiling, which are:

Percent of ceiling voltage	Field Voltage	S_E
100	3.0	0.388
75	2.25	0.138

[2]All values are per unit except time constants which are in seconds.

Utilizing these two values of the saturation function for their corresponding field voltage, the constants, C and K, of the previously structured function in equation (3.2) can be calculated.[3] The resultant expression given below is plotted in Figure 10.

$$S_E = 0.00654\, E_{FD}\, e^{0.995 E_{FD}} \tag{3.4}$$

The exciter constant, K_E, is defined equal to the value of S_E calculated at steady-state, by the convention of adjusting the field rheostat to eliminate any contribution from the amplidyne ($E_R = 0$). Examination of Figure 3 yields the relationship below:

$$E_R + (K_E - S_E)\, E_{FD} = E_E \tag{3.5}$$

The quantity E_E must be zero in order that E_{FD} remains constant (block (4) is an integrator) and with E_R equal to zero.

$$K_E = S_E \tag{3.6}$$

At steady state ($E_E = 0$), the relationship between the exciter ceiling voltage, the saturation function maximum and the amplidyne limit (field rheostat not adjusted), from equation (3.5) is:

$$V_{Rmax} + (K_E - S_{Emax})\, E_{FDmax} = 0 \tag{3.7}$$

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[3] See Appendix I for derivation of saturation function constants.

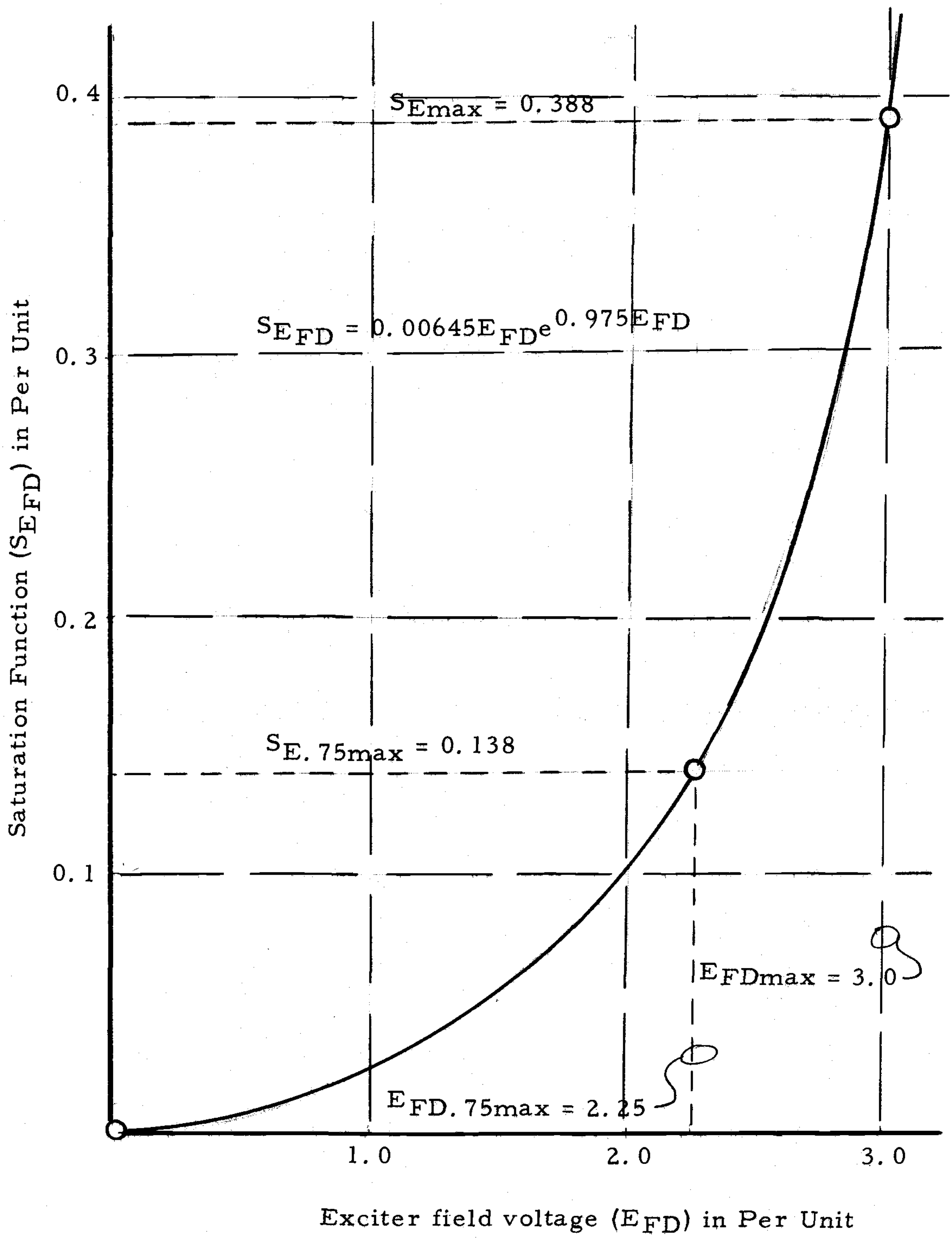

Figure 10. Graph of saturation function.

Provision for steady-stage voltage at the alternator terminals, independent of the supplied field excitation, is accomplished by setting K_G as follows:

$$K_G = \frac{1}{E_{FDO}} \tag{3.8}$$

Motivation for this initial adjustment of alternator gain is to provide rated terminal voltage under all variations of field excitation. In effect, K_G compensates for different values of load power factor. This gain adjustment is necessary to satisfy the initial assumption that the alternator operates into an infinite bus.

The effective time constant of the alternator model (T'_{DG}) can be calculated from the following specifications:

$$T'_{do} = 6.0 \text{ sec.}$$

$$X_d = 0.85 \text{ p.u.}$$

$$X'_d = 0.35 \text{ p.u.}$$

$$X_E = 0.15 \text{ p.u.}$$

From the relationship in equation (3.3):

$$T'_{DG} = 6.0 \left[\frac{0.35 + 0.15}{0.85 + 0.15}\right] = 3.0 \text{ sec.} \tag{3.9}$$

IV. SENSITIVITY STUDY

Simulator

The simulation of a mathematically-modelled system using digital programming requires the obvious, but important, initial decision of language selection. Continuously changing quantities including feedback loops are described most accurately by analog or hybrid computer systems. However, the relative ease of digital programming when combined with judicial control of the independent variable, time, presents a strong case for digital modelling. Leffler demonstrated that the digital-analog simulator language, MIMIC (10) provided an effective language for model simulation in sensitivity studies (9).

MIMIC utilizes FORTRAN-like statements for basic calculations and special functions to handle typical analog processes such as integration. Operating in a pseudo-parallel mode, MIMIC closely approximates the response of an analog system. Derivatives are handled quite easily for continuous variables but the excessive computation time required justifies replacement by an integration scheme, as derived in Figure 5. Integration is accomplished by a fourth-order Runge-Kutta method with error reduction by the Richardson extrapolator.

The key to the success of MIMIC is the precise control of time incrementations during transient situations. The time increment that specifies successive model execution times is automatically adjusted between a user-supplied minimum (DTMIN) and maximum (DTMAX) to insure a relative error of less than 5×10^{-6}. Judicial assignment of these two limits allows balancing accuracy requirements against total simulation time. A separate time control variable (DT) is used to determine when the designated quantities are to be saved for eventual output. DT is only changed by the program, giving the user complete control in scheduling output times.[4]

Coding of the MIMIC program representing the digital equivalent of the block diagrams in Figures 3 and 9 is segmented into the following phases:

1. Time control logic
2. Initialization
3. Voltage signal processing
4. Input and output

Values of the time constants within the model determine the execution time increment segmentation over the dynamic response interval. Adequate model performance can be obtained by requiring approximately ten executions during each time interval dominated by a particular time constant.

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[4]See MIMIC manual for more detailed information.

Specifications of values for DT_i and $DTMAX_i$ are identical except for i equal one (see Table 2). DT_1 was assigned twice the value of $DTMAX_1$ to eliminate excessive output of values for the initial sharply-rising transient. In accordance with the preceeding guide lines, the following correlation table was established providing time incrementation control.

Table 2. MIMIC program time control.

Time Constant and Nominal Value	Maximum Execution Interval	Output Time Increment
T_A = 0. 06 sec	$DTMAX_1$ = 0. 005	DT_1 = 0. 01
T_E = 0. 5 sec	$DTMAX_2$ = 0. 05	DT_2 = 0. 05
T_F = 1. 0 sec	$DTMAX_3$ = 0. 2	DT_3 = 0. 2
T'_{DG} = 3. 0 sec	$DTMAX_4$ = 0. 5	DT_4 = 0. 5

Experimentation revealed that equating DTMIN to 0. 00001 for the entire simulation was a suitable compromise that provided sufficient accuracy without an appreciable increase in simulation time. An added dimension of credibility in transient studies is achieved by demonstrating the system to be operating under steady-state conditions prior to a disturbance. Therefore, the perturbation of E_{REF} (DELETR in the program) was initiated after 0. 195 seconds of simulation. This seemingly odd value was selected to allow two data points, indicating no field voltage change, under the internal logic control of MIMIC. A summary of the significant time points is illustrated on the non-linear time axis below, with output data points depicted as short, dark tics.

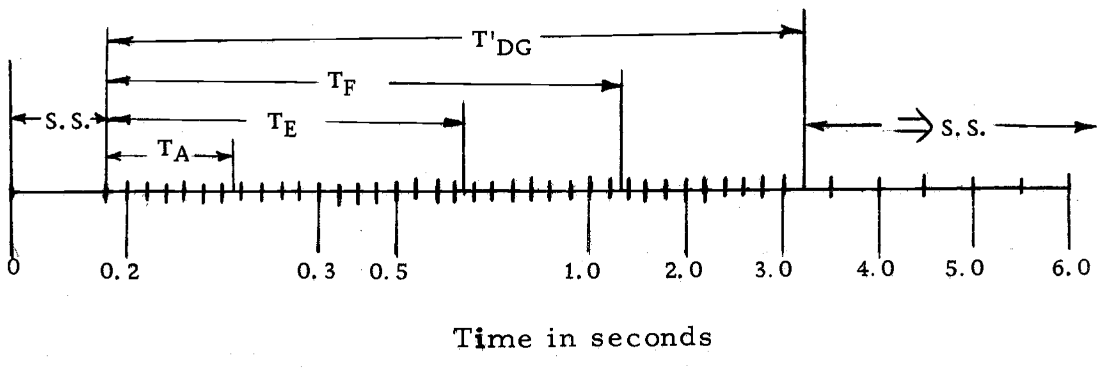

Figure 11. Time control.

Initialization is accomplished at time equal to zero (T_0) and includes the following:

1. Establishment of voltage regulator limits (VRMAX, VRMIN).
2. Specification of defining points for the saturation function.
3. Establishing steady-state conditions by maintaining E_{REF} constant.
4. Initialization of the alternator gain (KG) according to equation (3.8).
5. Establishing initial alternator terminal voltage (ET = 1.0).
6. Calculation of saturation function constants (C, K) from the equations developed in Appendix I.
7. Equating exciter constant, K_E, equal to the initial value of the saturation function, S_E.

Because MIMIC operates in a pseudo-parallel mode, all program statements appear to be executed simultaneously. This feature enables complex circuits to be coded without regard to ordering (which is accomplished by a Sorted Function Generator within MIMIC). Program statements computing voltage signals were written directly from the block diagrams in Figures 3 and 9. Special MIMIC functions for integration (INT), first-order transfer functions (FTR) and limiter (LIM) were used as required.

Seven quantities, comprising two fixed-format data cards, are specified for each simulation. The first card designates the following quantities: a simulation identification number (IDNO), the initial field voltage (EFDO) and the magnitude of the perturbation of E_{REF} (DELETC). The second card contains values for the six exciter parameters being studied, in the order listed: K_A, T_A, SAT1, T_F, T_E, and K_F. The quantity SAT1 is the value for the saturation function at 75 percent ceiling field voltage, thus making the saturation function a variable. Output quantities are time and corresponding exciter field voltage values, in a fixed format, that follows the automatic listing of the seven input variables. Batch simulation is accomplished by including additional input cards in sets of two. All model variations were simulated to six seconds in real time.

The MIMIC program was executed on the Control Data Corporation Model 3300 computer facility at Oregon State University. Output was accumulated on magnetic tape for sensitivity evaluation. Program listings and the associated flow diagram are included in Appendix II.

Data Processing

A knowledge of the quantitative values defining a system and its associated exciter field voltage response is sufficient to calculate parameter sensitivities. Parametric sensitivity is derived from the difference in response of the same system differing only by a known variation of one parameter. Specifically for this study, the definition below will be used.[6]

$$S_P^{E_{FD}}(t) = \frac{P\, dE_{FD}(t)}{E_{FD}(t)\, dP} \tag{4.1}$$

where: $S_P^{E_{FD}}(t)$ is the sensitivity at some instant, t, due to an exciter parameter differential, dP, causing an associated exciter field voltage differential ($d\,E_{FD}$).

The above definition of sensitivity involves one dependent variable, $dE_{FD}(t)$ as a function of two independent variables: time and dP. The complexity increases when this dependent variable is divided by another dependent variable, $E_{FD}(t)$, and multiplied by the constant P. In order to make the expression manageable, the time independent variable dP can be replaced by:

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[6] E_{FD} in $S_P^{E_{FD}}(t)$ is a descriptive superscript, not an exponent.

$$\Delta P = P_1 - P_2 \qquad (4.2)$$

where: P_1 and P_2 are different pre-determined values of the same parameter for two model simulations.

This approximation is appropriate for the study because the objective is to determine the parametric sensitivity due to specific changes.

As a result, the term d $E_{FD}(t)$ can now be replaced by:

$$\Delta E_{FD}(t) = E_{FD}(t)_1 - E_{FD}(t)_2 \qquad (4.3)$$

Digital calculation of the sensitivity of any defined value of t, can now easily be accomplished by the equation:

$$S_P^{E_{FD}(t)} = \frac{P\left[E_{FD}(t)_1 - E_{FD}(t)_2\right]}{E_{FD}(t)\left[P_1 - P_2\right]} \qquad (4.4)$$

System analysis requires meaningful comparisons between sensitivities of two or more parameters or the comparison between sensitivities of the same parameter with different values. A common base for comparisons can be achieved by numerical specification of all system quantities, thus defining a particular model as a "nominal" system. The sensitivity equation in (4.4) can be generalized upon a common base:

$$S_{P_T}^{E_{FD(t)}} = \frac{P_T\left[E_{FD}(t)_T - E_{FD}(t)_N\right]}{E_{FD}(t)_T\left[P_T - P_N\right]} \qquad (4.5)$$

where the subscripts T and N indicate the values associated with the test and nominal models, respectively.

Data processing, such as the sensitivity calculation, is not practical using MIMIC because of the difficulty in correlating simulations through the rigid and limited I/O facilities. Simulation outputs, serially formatted on magnetic tape, and mathematical calculations are easily accommodated by FORTRAN. Programming ease, flexibility and prior knowledge dictated that sensitivity processing using FORTRAN was a logical choice.

In addition to reading simulation results and calculating sensitivities, an equally important function of this program is to display the sensitivities and the conditions that define the models involved. Three areas of information were deemed important to present a complete set of data representing the study:

1. Values for all input variables
2. Tables of sensitivity versus time
3. Tables displaying field voltage versus time

A fourth output graphically illustrating the sensitivity response versus time was implemented as a desirable option, aiding quick comparisons.

As suggested previously, often the difference in sensitivities between two systems, differing only by a known amount in one or more parameters, contains more useful information than simply the magnitude of a particular parametric sensitivity as a function of time. To facilitate such comparisons, a maximum of six output quantities can be listed adjacently and/or plotted on the same time axis. Field voltage responses and sensitivities are listed on separate sheets in a columnar format.

Meaningful comparison of two or more sensitivity responses must have, as a common basis, the same values of the steady-state field voltage (EFDO) and the magnitude of the perturbation of reference voltage, E_{REF} (DELETC). All other system parameters except the six being studied are held constant by the MIMIC program; thus only these six parameters can determine a variation in field voltage response. Any response from a group of models, with the common attributes described above, can be selected to serve as the nominal system. Program simplicity was accomplished by requiring the first simulation output read from magnetic tape to be declared the nominal case.

Selection of sensitivity responses to be calculated and displayed is accomplished by labeling each model's field voltage response with a unique identification number (IDNO). The user selects from two to six identification numbers, in sequential order on magnetic tape, for a particular study. The input data is stored in two dimensional arrays. To accommodate the rigid output format of MIMIC, the input coding must also conform to the same framework.

The output, including the graphic display, can be divided into three 'pages' by combining items (1) and (2) on page 29.[5] Conversion of parameter values to percent of the respective value for the nominal model was implemented to allow quicker recognition of differences. The actual per unit values for the nominal model were retained, to provide an absolute reference. The first portion of page one lists all common initial conditions, the nominal parameter values and the percent representation for all other models. The remainder of page one contains computed sensitivity values based on the nominal system using equation (4.5).

Page two provides a dump of field voltages versus time contained in the input array. Because MIMIC cannot release data to both a magnetic tape unit and a line printer during the same run, this display serves as a reference to the non-visual MIMIC output.

Graphical display of the compûted sensitivites, printed on page three, provided the most problems. Considering the large quantity of sensitivity plots planned and the economics involved, the X - Y plotter was not utilized. However, an efficient method of displaying variables,

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[5]See Appendix I for 'page' composition definitions.

especially suited for discrete time samples, is simply using the line printer as a plotter (12). The dependent variable can have as many discrete states as the number of printer character positions. Successive print lines provide for discrete advancement of the independent variable. Plotting transient response where the period of oscillation varies with time causes a real problem in scaling a uniform time increment. This author chose initially to use a non-linear time axis with the following time increment and associated sensitivity value placed on the next line. Although the plot was concise, it lacked smoothness because of discontinuities introduced when the time increment was changed. As a consequence, a linear time axis was employed with the compromise that the selected time increment per line would be 0.05 seconds. The effect of this change was to more than double the amount of paper required and eliminate plotting eight values describing the initial transient.

Scaling the sensitivity axis also required several important decisions. In the original non-linear version, each sensitivity was scaled independently, enabling maximum use of 100 discrete magnitude positions. This independent scaling was considered necessary because of nearly an order of magnitude difference between maximum value of one sensitivity compared to that of another. However, the difficulty in obtaining quick comparisons between responses overweighed the importance of maintaining a large variation for each individual response. In later versions of this program, a common scaling factor was substituted, calculated by assigning the largest magnitude deviation of all sensitivities equal to the maximum plot position.

Values of sensitivity can be either positive or negative depending upon the sign of the resultant quantities enclosed in brackets in equation (4. 5). The sign of a sensitivity value provides the relationship between parameter variation and increase or decrease in field voltage. Thus preserving the sign of the sensitivity will indicate the polarity of the field voltage deviation with respect to the polarity of the parameter deviation. Conversely, a claim can be justified in dropping the sign by declaring the object of the sensitivity study is to show only whether or not the system is sensitive to a particular parameter change. Originally, this program did not allow for the latter philosophy, but later revisions provide the option of an absolute value plot. An absolute value plot has the advantage of utilizing twice as many discrete plot positions, thus obtaining greater resolution.

Accommodation for two or more values from different sensitivity plots falling on the same character position was accomplished by forcing overprinting as required.

Provisions are included to permit comparisons of field voltage responses due to changes in more than one parameter. A mathematically rigorous approach to polyparametric sensitivity studies requires finding the maximum of the partial derivative of the response with respect to one of the variable parameters over the transient time interval (9). Instead of constructing a more difficult routine to study polyparametric sensitivity per se, this author chose to compare the normalized differences of the field voltage responses without attempting to separate individual parameter effects. The equation below depicts the relationship to be utilized:

$$S_{NDR}^{E_{FD}}(t) = \frac{E_{FD}(t)_T - E_{FD}(t)_N}{E_{FD}(t)_N} \tag{4.6}$$

where: $S_{NDR}^{E_{FD}}(t)$ is called the normalized differential exciter field voltage response (NDR)

This quantity is designated by an "S" because it represents the total sensitivity of the system.

The normalized differential response is clearly not a polyparametric sensitivity, but has the power required to serve further research.

Other options selected at input time that may be desirable are listed below:

1. Ability to delete computations and listing associated with any of the output pages.
2. Selection of the number of responses to be compared (maximum of six against the nominal response).

3. Plotting dimensions, including time axis increment and cut-off time.

4. Instead of computing sensitivity according to equations (4. 5) or (4. 6), a third algorithm may be supplied by the user, as a subroutine.

5. More than one set of data may be compared against a nominal response by utilizing a 'batch' processing mode.

Details of the design of this program are provided in the listings in Appendix II.

Test Implementation

As set forth in the objectives, a comprehensive parameter sensitivity study is beyond the scope of this project. Instead, the desire is to demonstrate the utility of the two programs under a wide range of input variables.

Fifty-two independent simulations with the MIMIC program were selected to provide a broad coverage of the six exciter parameters subject to testing. Four values of initial field voltage were tested, each at 10 percent and 20 percent deviations of the six parameters, individually. To provide a suitable nominal response for sensitivity computation, a simulation with all parameters equal to previously assigned nominal values was necessary for each of the four field voltages. Table 3 provides a useful guide by associating an assigned identification number (IDNO) with each test, for referencing convenience. Parameter values at zero percent variation (nominal) are consistent throughout the tests as defined in Table 1, Chapter III.

Table 3. Index for associating variable parameter values to assigned identification numbers.

Exciter Field Voltage	Percent Parameter Variation from Nominal Value	Variable Parameter					
		TA	KA	SAT1	TF	TE	KF
1.0	0	100 (200)					
	10	101	102	103	104	105	105
	20	201	202	203	204	205	206
1.5	0	300 (400)					
	10	301	302	303	304	305	306
	20	401	402	403	404	405	406
2.0	0	500 (600)					
	10	501	502	503	504	505	506
	20	601	602	603	604	605	606
2.5	0	700 (800)					
	10	701	702	703	704	705	706
	20	801	802	803	804	805	806

Another input variable, adjusted several times, was the magnitude of the perturbation (DELETC). A DELETC equal to 0.01 was found to provide consistently, a field voltage deviation of less than ten percent.

Eight composite simulations, one for each series, were required to compute and display the sensitivities listed in Table 3. Three different representations of output page three were tested, which includes two linear, positive/negative plots, one linear, absolute value plot and five non-linear, positive/negative plots. A complete set of data for these models comprise Appendix III.

V. ANALYSIS OF RESULTS

A complete study of the parametric sensitivities is not the objective of this thesis, as previously stated. The 52 simulated models were designed to span a wide range of system parameter specifications for demonstrating the utility of this software package. Most likely, more information is contained in these test results than can be rightfully subjected to analysis. More simulations investigating a particular phenomenon would be required to achieve a high level of credibility. However, selective analysis of these results will reveal a number of significant system response characteristics.

Before proceeding to specific quantitative analyses, several comments pertaining to the interpretation of the graphical sensitivity displays are necessary.

Three graphical formats were utilized for displaying sensitivities in order to demonstrate the flexibility of the FORTRAN data processing program. Although each format would provide the same scalar sensitivity magnitude for a given time from a given model, the method of representation is different. The following table is provided as an index relating the model simulation series to the graphical format employed.

Table 4. Index correlating graphical format to simulation series.

Series Identification Number	Format of Graphical Output
100, 200	linear, positive/negative values
300	linear, absolute values
400-800	non-linear, positive/negative values

Simulation series 100 through 300 provides plots based on a common sensitivity scaling factor for all responses on the same time axis. This feature enables easy visual comparison. However, a serious drawback is the accompanying trait of losing meaningful plots of responses with relatively small variations. This characteristic is exemplified by responses numbers 103.1 and 203. 1. Individual response scaling, as in simulation series 400 through 800, resulted in the opposite effect; that is, the ease of comparison is greatly diminished but relatively low magnitude variations are expanded. The absolute value plot (series 300) is somewhat a compromise, resulting from doubling the number of discrete plot levels while retaining the common scaling factor. However, the necessity to estimate projections to the zero magnitude level, if that condition does indeed exist, is an obvious disadvantage.

Utilization of discrete level plotting techniques require the interpreter to fit a curve through the printed data points. Linear interpolation does not provide a realistic curve for highly transient responses. In these situations, the interpreter must fashion a smoother curve, relying on additional knowledge. The output voltage response of an excitation system (functioning normally) will not contain discontinuities, because of its associated momentum. Therefore, the sensitivity response, being a function of the output voltage, will be a smooth, continuous curve. Connection of consecutively plotted data points with line segments or properly shaped curves to portray a smooth response would appear to solve the graphing problem. For relatively large sensitivity variations, this technique provides a satisfactory approximation. But for small variations, the necessary error due to quantizing the sensitivity magnitude must be considered. This error can be termed a round-off error, with a maximum magnitude of one half of a character position.[7] Simulation number 303.1 best exemplifies the effect of poor plotting resolution resulting from the round-off effect. Data from the associated sensitivity table contained on output page one can be used to correctly fit a curve to low level sensitivities. The methods explained above were utilized by the author in fitting curves to the data plots in Appendix III.

Non-linear time axis plots are concise, but somewhat deceptive. Discontinuities in the slope of the sensitivity response appear where the time axis increment changes value. Although curve fitting will yield fairly accurate sensitivity magnitudes compared to its associated sensitivity table, the smoothness quality is lost.

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[7]See FORTRAN program listing for additional information.

As previously stated, all simulations were carried out to six seconds. However, graphic representations, in most cases, were terminated at four seconds to accommodate acceptable display arrangements for this thesis. No significant information was deleted by this procedure.

Sensitivity output from the simulation series 200 was computed using the normalized differential response relationship, (4.6), in contrast with all other simulation computations which utilized equation (4.5). Although nearly an order of magnitude difference exist in table entries due to computation by the two sensitivity algorithms, the graphical representations are nearly identical.[8] This difference in tabular values must be considered when comparing simulation series 200 with any other included series.

With the above graphic considerations in mind, general observations of some significant parametric effects will now be detailed. Although the following analyses are derived from graphical representation of the sensitivities, the tabular data is valuable in a supporting role.

1. The time required for the system to attain steady-state operating conditions following a perturbation is considerably greater for systems with a larger initial field voltage.

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[8] Compare simulation series 100 and 200.

The stabilization time ranges from approximately 2.5 seconds at 1.0 per unit field voltage to over six seconds at 2.5 per unit field voltage.

2. All six exciter parameters exhibit both positive and negative sensitivites during every simulation. Accordingly, there exists at least one point in time during the simulation for which the sensitivity is zero. In other words, the system is insensitive to any change in that parameter at that particular instant.

3. The number of oscillations of a sensitivity response is dependent upon the initial field voltage and the particular parameter. For example, the sensitivity response of T_A passes through zero four times with $E_{FDO} = 1.0$ but only once with $E_{FDO} = 2.5$. The nearly inverse relationship is observed for the parameter S_E (SAT1) which has no appreciable effect at $E_{FDO} = 1.0$ but with $E_{FDO} = 2.5$, the saturation sensitivity is still significant beyond six seconds.

4. Maintaining all other variables constant, an increase from 10 percent to 20 percent parameter deviation greater than its nominal value does not significantly alter the sensitivity response. Sensitivity variations are correspondingly greater but the number and relative position of the sensitivity oscillations remain unchanged. This phenomenon can be verified by overlaying any two sensitivity series plots of the same format with identical

initial field voltages.

5. The parameter T_F exhibits a significant sensitivity value over the greatest time for low values of initial field excitation. The parameters, T_F, K_F, and SAT1, exhibit much longer non-zero sensitivities compared to the sensitivities of the other three parameters at high values of initial field voltage.

6. Three parameters, K_A, T_A, and T_E, contribute nearly all of the system sensitivity associated with the initial, sharply-rising transient over the first 0.1 second after the perturbation. This effect involving K_A and T_A is expected because the amplidyne is the most rapidly responding device in the system. Rapid response of the same order from the exciter (T_E) which has a much longer time constant is not so obvious. A study of this phenomenon from all simulation series showed a high degree of independence from initial field excitation and small test parameter variations.

7. The sensitivity of the saturation variable, (SAT1), appears to show the most significant deviation over the entire simulation tests. For all tested values of the initial field voltage, except $E_{FDO} = 2.5$, the magnitude of the maximum saturation sensitivity is approximately 15 percent or less of the next least sensitivity parameter, T_A. Neglecting the saturation effect would appear to be a reasonable assumption for these lower field excitations. However, sensitivity simulations 703 and 803 ($E_{FDO} = 2.5$)

indicates that the saturation effect is significant, particularly after the first two seconds.

The polarity of the saturation sensitivity is observed to reverse, as a function of initial field voltage. This change occurs between initial field voltage values of 2.0 and 2.5. Considering the manner in which the saturation function was made variable, this unexpected phenomenon can be explained. Figure 12 and the following examination will clarify the above statements. Figure 12 shows the comparison between the form of the saturation function nominally defined and a 20 percent increase, utilizing the method of variation established in Chapter IV. Because of the difference in slope of the two curves for corresponding time values, the variation of the saturation function over its dynamic range will provide the following inequalities:

$C > D$ for all values of E_{FDO} less than some E_{FDO} near 2.25.

$A < B$ for all values of E_{FDO} greater than that same E_{FDO} near 2.25.

A greater dynamic range of the saturation function will result in more negative feedback to the exciter model input, thus decreasing the quantity E_E (see Figure 3). Accordingly, a smaller field voltage at corresponding time samples will be produced during the operation along the dynamic ranges B and C

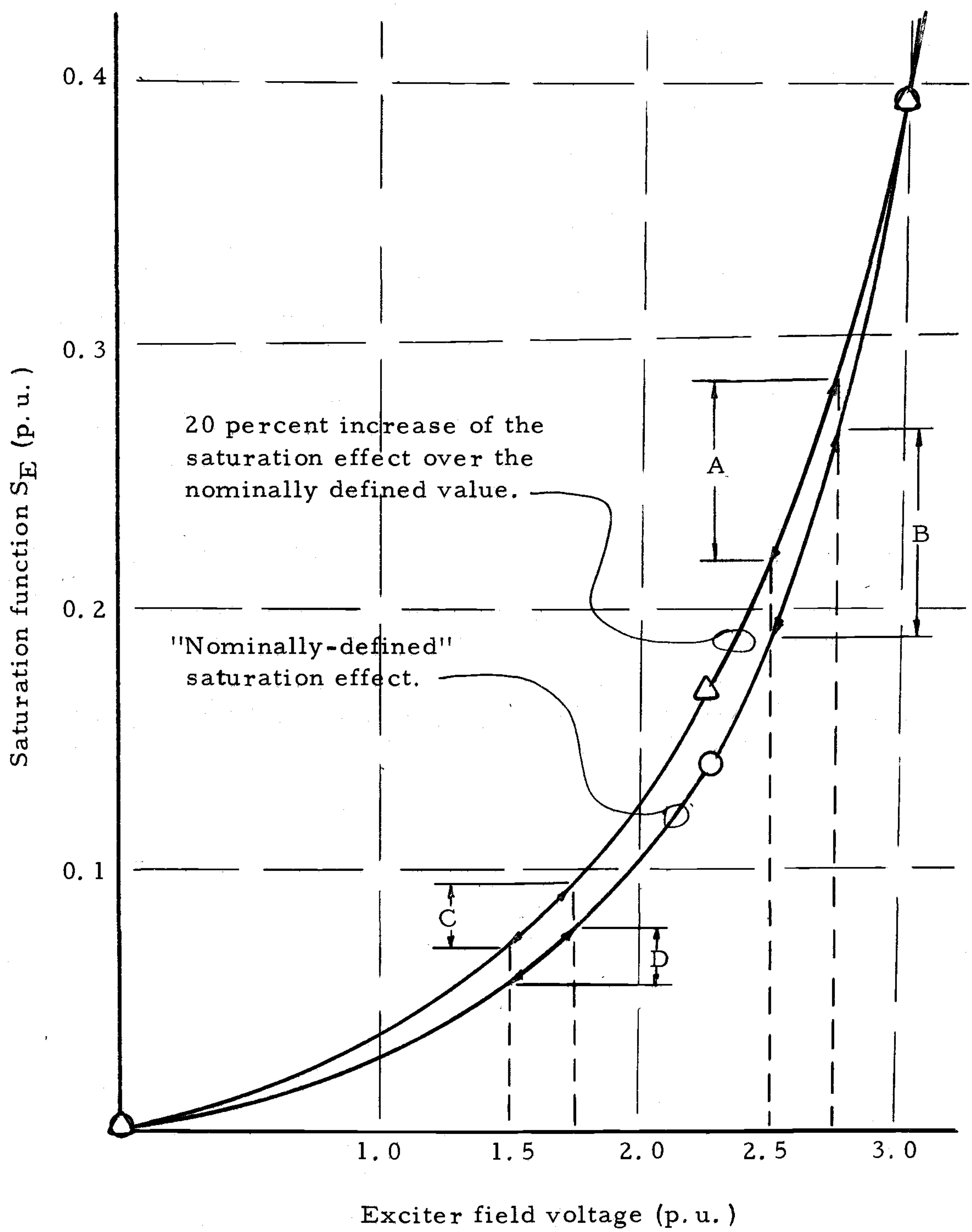


Figure 12. Effect of varying the saturation function.

compared to A and D, respectively. Considering the sensitivity calculation according to equation (4. 5), the sensitivity polarity reversal becomes apparent. Thus the reversal of polarity for the saturation sensitivity responses is the result of the method employed to vary this function.

In compliance with previously stated objectives, further analysis of the sensitivity results, dwelling on a particular parameter, is not feasible based on the information available.

IV. CONCLUSIONS

This investigation has dealt with a rather specific generation system. Detailed modelling was confined to the excitation system. A number of assumptions involving modelling of the alternator and voltage regulator were employed to construct a feasible system for computer analysis. This procedure enabled major emphasis to be placed upon implementing an excitation system model which could be subjected to parameter variations. Perturbation of the steady-state system model was accomplished internally, by resetting the regulator reference voltage. The response obtained from this model simulation should not be confused with a response caused by a change in alternator loading.

Before listing specific conclusions, the author strongly believes that the philosophy behind studies involving modelling deserves reviewing.

At best, a model is only a means of approximating a physical system. There exists several other excitation system models, some more complex than the IEEE Type 1 utilized in this study. However, the selection of a model with respect to its complexity should be evaluated in the light of the knowledge (or lack of knowledge) of the physical system represented. For instance, the confidence interval evaluated for a particular significance level associated with the input data and supposedly "known" parameter values should be considered in evaluating the response of the model.

The implication of the above philosophy to this study is the realization that the sensitivity data and analysis clearly pertains to the model. The difficulty (perhaps impossibility) of obtaining field data from this physical system prohibits any direct comparison between model response and equipment response. If field data were attainable but contained a maximum of five percent error (a realistic value), the corresponding model response could not be compared to the field response at a significance level of less than 5 percent. The point is, that model refinement greater than the ability to appraise the physical system represented can serve only to analyze the model's performance, not that of the physical system.

Accordingly, the following conclusions pertain to this system model. The relationship of the model response to the physical system's response is a function of the assumptions accepted in deriving the model. The hope is that the correlation is acceptably high.

1. Digital programming of an analog system can be successfully accomplished providing time incrementation is closely regulated, as in MIMIC.
2. Discrete data point plotting using the line printer provides a useful method for displaying output responses. However, care must be exercised in interpreting the plotted data points,

especially for low magnitude values and highly transient situations.

3. Each plotting format has some advantages and disadvantages. The author believes the linear time axis, positive/negative value plot conveys the most information in the easiest form to analyze.

4. The most important variable in determining the system response characteristics is the initial value of the exciter field voltage. The shape of an exciter parameter sensitivity response is more dependent upon initial field voltage than on the value of the parameter itself.

5. Exciter field saturation significantly affects the field voltage response for relatively large initial values of field voltage. This is the primary reason for a greater transient time period following a perturbation of such models.

6. Sensitivity responses clearly indicate which parameters have the most effect in altering the field voltage response at any particular time.

7. A thorough analysis of the influence of parameter variations on the model's response should be based on a greater number of simulations pertaining to that area of special interest.

BIBLIOGRAPHY

1. Baba, J. *et al.* Sensitivity analysis of power system stability. In: Institute of Electrical and Electronics Engineers Power Industry Computer Applications Conference Record, Pittsburgh, 1967. p. 47-68.

2. Crenshaw, M. L. Notes on the evolution of representations for rotating exciters. Schenectady, New York. Sept. 16, 1969.

3. Cresap, R. L. Modeling of salient pole hydro-generators. U.S. Army Corps of Engineers, Portland, Oregon. [April 1970]

4. Institute of Electrical and Electronics Engineers. Power Generation Committee. Excitation Systems Subcommittee. Computer representation of excitation systems. New York, 1967. 5 p. (Paper no. 31TP67-424)

5. ________________ Proposed excitation system definitions for synchronous machines. New York, 1969. 15 p. (Paper no. 69TP154-PWR)

6. Kasturi, R. and P. Doraraju. Sensitivity analysis of power systems. Institute of Electrical and Electronics Engineers, Transactions on Power Apparatus and Systems 88:1521-1529. 1969.

7. ________________ Relative dynamic stability regions of power systems. Institute of Electrical and Electronics Engineers, Transactions on Power Apparatus and Systems 89:966-974. 1970.

8. Leffler, Fred R. Digital simulation of non-linear voltage regulation systems. Master's thesis. Corvallis, Oregon State University, 1969. 82 numb. leaves.

9. ________________ On the polyparametric sensitivity of Park's equations by computer simulation methods. Doctoral dissertation. Corvallis, Oregon State University, 1970. 45 numb. leaves. (Microfilm)

10. Skinner, David and Fred R. Leffler. MIMIC - a digital-analog simulator. Corvallis, Oregon State University. Computer Center. 1969. 48 p. (Manual no. cc-69-5)

11. Teichgraeber, Richard D., Floyd W. Harris and Gary L. Johnson. New stability measure for multimachine power systems. Institute of Electrical and Electronics Engineers, Transactions on Power Apparatus and Systems 89:233-239. 1970.

12. Woolfson, M. G. Plotting program handles multivalued functions. Electronics, July 5, 1971. p. 67-69.

APPENDICES

APPENDIX I

a. Symbol List

Quantity	Equivalent Program Label	Definition
C	C	saturation function constant
d	---	derative operator
---	DELETC	change in regulator reference voltage
---	DELETR	current value of the regulator reference voltage, which is initially zero.
---	DT	MIMIC output time increment
---	DTMAX, DTMIN	MIMIC execution time increment limits
E_A	EA	amplidyne output voltage
E_{B4}	EB4	exciter stabilization voltage
E_{B6}	EB6	exciter stabilization circuit voltage
E_E	EE	internal exciter voltage
E_{FD}	EFD	exciter output voltage
E_{FDO}	EFDO	steady-state exciter output voltage
$E_{FD\ ceiling\ (or\ max)}$	SATE2	maximum exciter voltage

Quantity	Equivalent Program Label	Definition
$0.75E_{FD}$ ceiling (or max)	SATE1	0.75 times maximum exciter voltage
E_I	EI	amplidyne input voltage
E_K	EK	voltage due to self-excitation
E_R	ER	amplidyne limiter output voltage
E_{REF}, V_{REF}	---	voltage regulator reference voltage
E_S	ES	voltage due to saturation effect
E_T	ET	alternator terminal voltage
ΔE_T	DELET	error signal from voltage regulator
---	IDNO	simulation identification number
K	K	saturation function constant
K_A	KA	amplidyne gain
K_E	KE	exciter constant related to self-excited field
K_F	KF	stabilization circuit gain
L_{EF}	---	exciter field inductance

Quantity	Equivalent Program Label	Definition
L_{GF}	---	alternator field inductance
N	---	subscript indicating nominal value
P	---	parameter
Page one	IP1	FORTRAN output listings containing system parameter and sensitivity table
Page two	IP2	FORTRAN output listing containing the simulated exciter voltage table
Page three	IP3	FORTRAN output listing containing a graphical plot of the sensitivity data
R_{EF}	---	exciter field resistance
R_{GF}	---	alternator field resistance
$R_{RHEOSTAT}$	---	resistance of exciter field rheostat
s	---	Laplacian operator
S	SNTV	sensitivity
S_E	SE	saturation function
S_{Emax}	SAT2	value of saturation function at exciter ceiling voltage
$0.75S_{Emax}$	SAT1	value of saturation function at 0.75 exciter ceiling voltage
SYSTEM	---	the specific electrical assembly as shown in Figures 3 and 9

Quantity	Equivalent Program Label	Definition
t	T, TIME	time
T	---	subscript indicating a test value
T_A	TA	amplidyne time constant
T'_{do}	---	open-circuit, direct-axis transient time constant of the alternator
T'_{DG}	TG	effective alternator transient time constant
T_E	TE	exciter time constant
T_F	TF	stabilization circuit time constant
T_R	---	regulator filtering time constant
V_{Rmax}, V_{Rmin}	VRMAX, VRMIN	amplidyne voltage regulator limits
X_d	---	alternator direct axis synchronous reactance
X'_d	---	alternator direct axis transient reactance
X_E	---	alternator armature leakage reactance

b. Calculation of Saturation Coefficients in Terms of the Given Data

The details involved in solving for constants C and K, as referenced on page 19 are provided below.

Solving for the coefficients, C and K, in terms of the two given saturation coordinates involves the simultaneous solution of two equations with two unknowns. Utilizing equation (3.2), the saturation function must pass through the two points given below:

$$S_{max} = (K)\,(E_{FDmax})\,e^{(C)(E_{FDmax})}$$

$$S_{.75max} = (K)\,(E_{FD.75max})\,e^{(C)(E_{FD.75\,max})}$$

Using a shorter notation for convenience:

$$S_1 = S_{max} \qquad E_1 = E_{FDmax}$$

$$S_2 = S_{.75max} \qquad E_2 = E_{FD.75max}$$

the following relationships provide the exact expressions for coefficients C and K:

$$\ell n\, S_1 = \ell n K + \ell n\, E_1 + E_1 C \tag{A.1}$$

$$\ell n\, S_2 = \ell n\, K + \ell n\, E_2 + E_2 C \tag{A.2}$$

Eliminating the unknown, K, by subtraction, then regrouping:

$$\ell n\, S_1 - \ell n\, E_1 - E_1 C = \ell n\, S_2 - \ell n\, E_2 - E_2 C$$

$$C = \frac{\ell n\, S_2 - \ell n\, S_1 - \ell n\, E_2 - \ell n\, E_1}{E_2 - E_1}$$

and finally condensing the logarithms:

$$C = \frac{\ell n \left[\dfrac{E_1 S_2}{E_2 S_1}\right]}{E_2 - E_1} \qquad (A.3)$$

Solving for K by eliminating C from (A. 1) and (A. 2) and equating the two expressions gives:

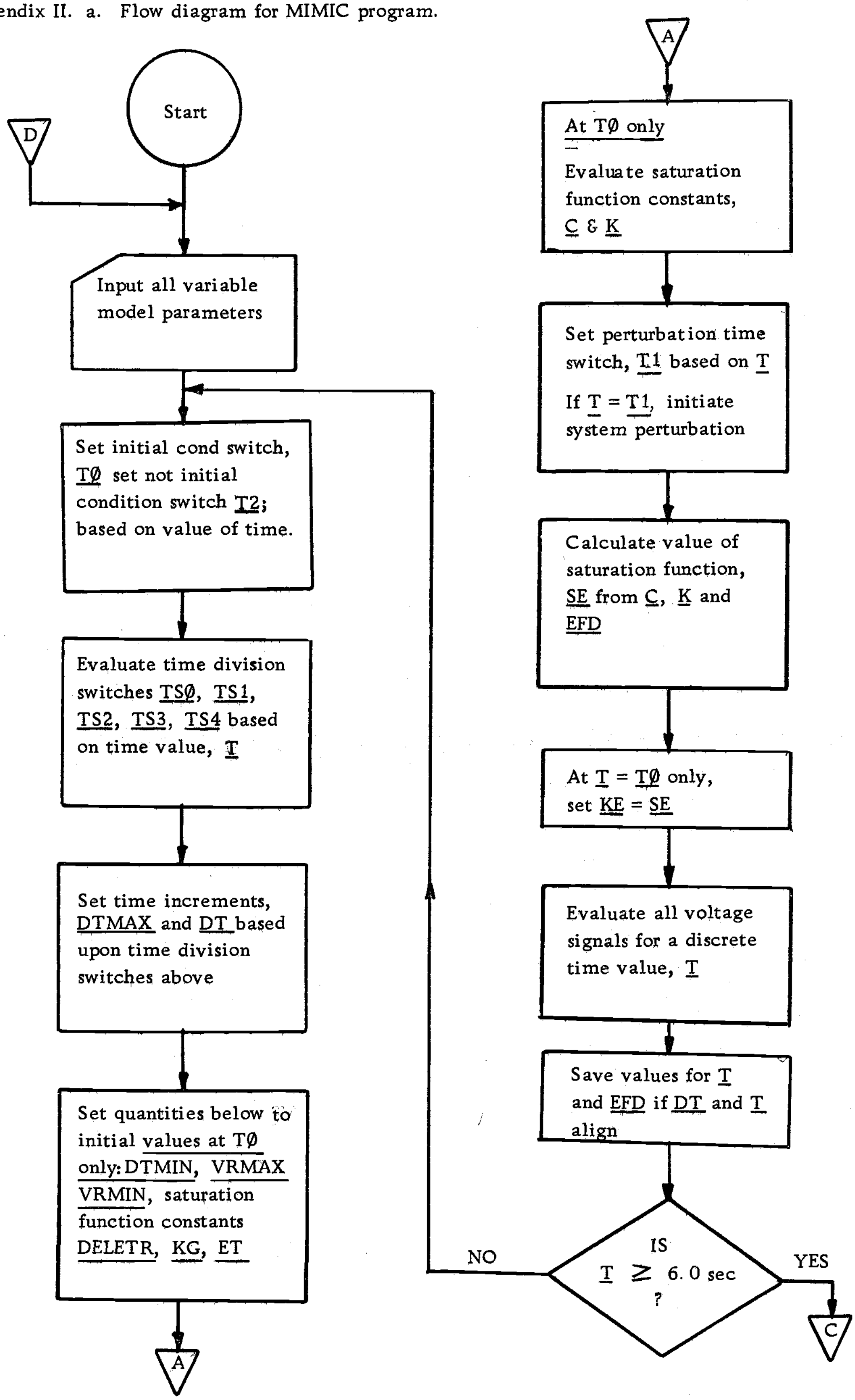
$$-E_2\, \ell n\, S_1 + E_2\, \ell n\, K + E_2\, \ell n\, E_1 = -E_1\, \ell n\, S_2 + E_1\, \ell n\, K + E_1\, \ell n\, E_2$$

$$\ell n\, K = \frac{E_2\, \ell n\, S_1 - E_2\, \ell n\, E_1 - E_1\, \ell n\, S_2 + E_1\, \ell n\, E_2}{E_2 - E_1}$$

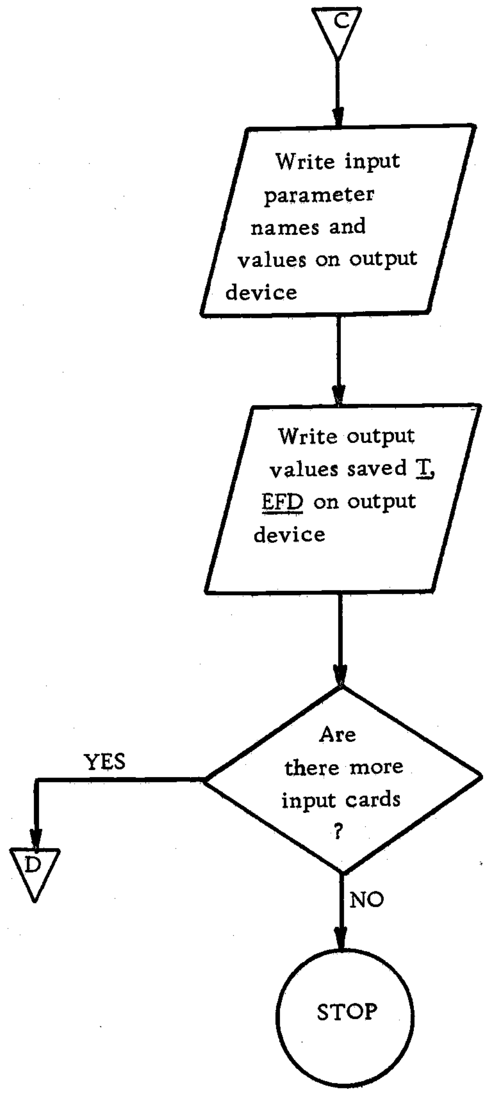
Mathematical condensation yields:

$$K = \exp \frac{E_2\, \ell n \left[\dfrac{S_1}{E_1}\right] - E_1\, \ell n \left[\dfrac{S_2}{E_2}\right]}{E_2 - E_1} \qquad (A.4)$$

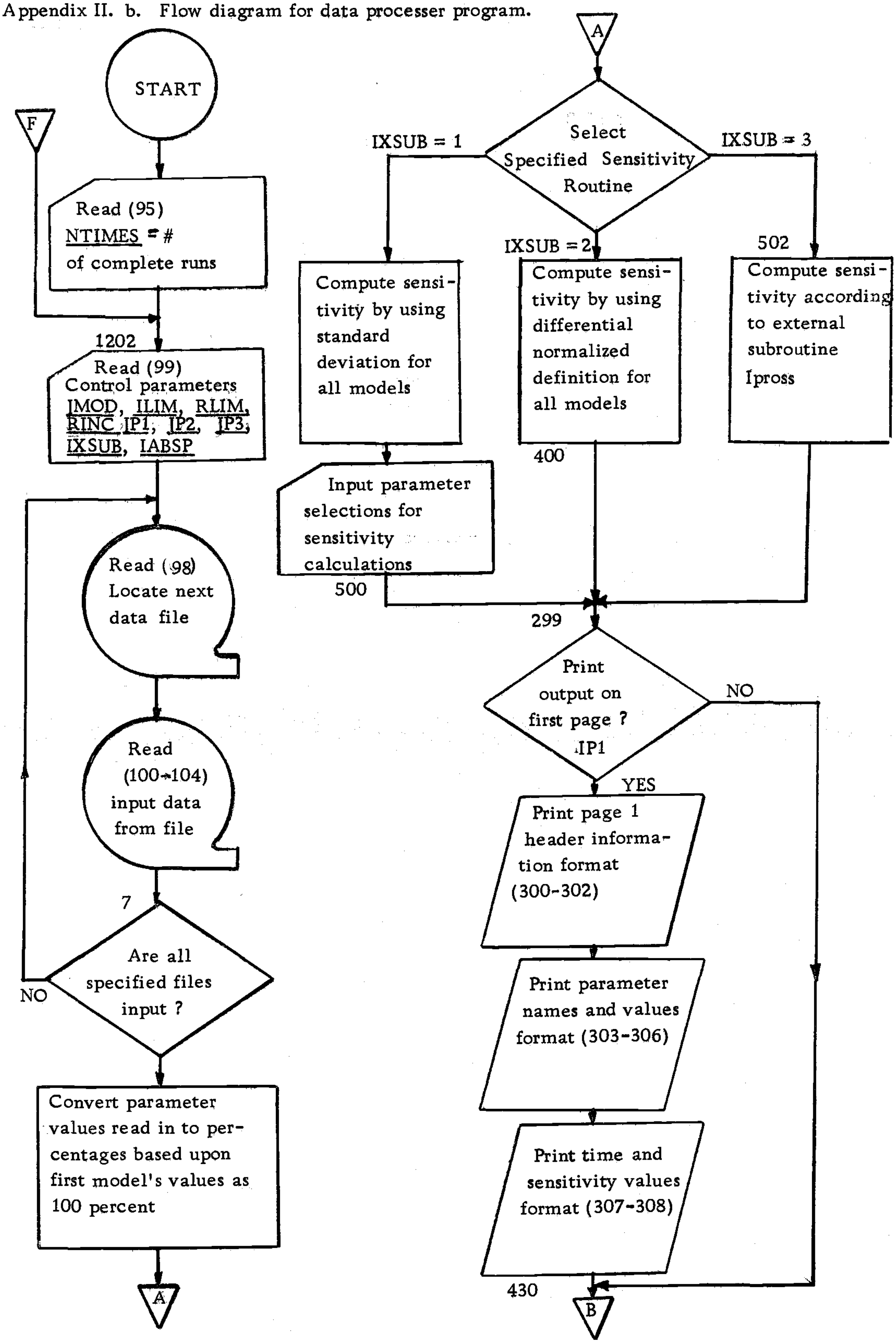
Appendix II. a. Flow diagram for MIMIC program.



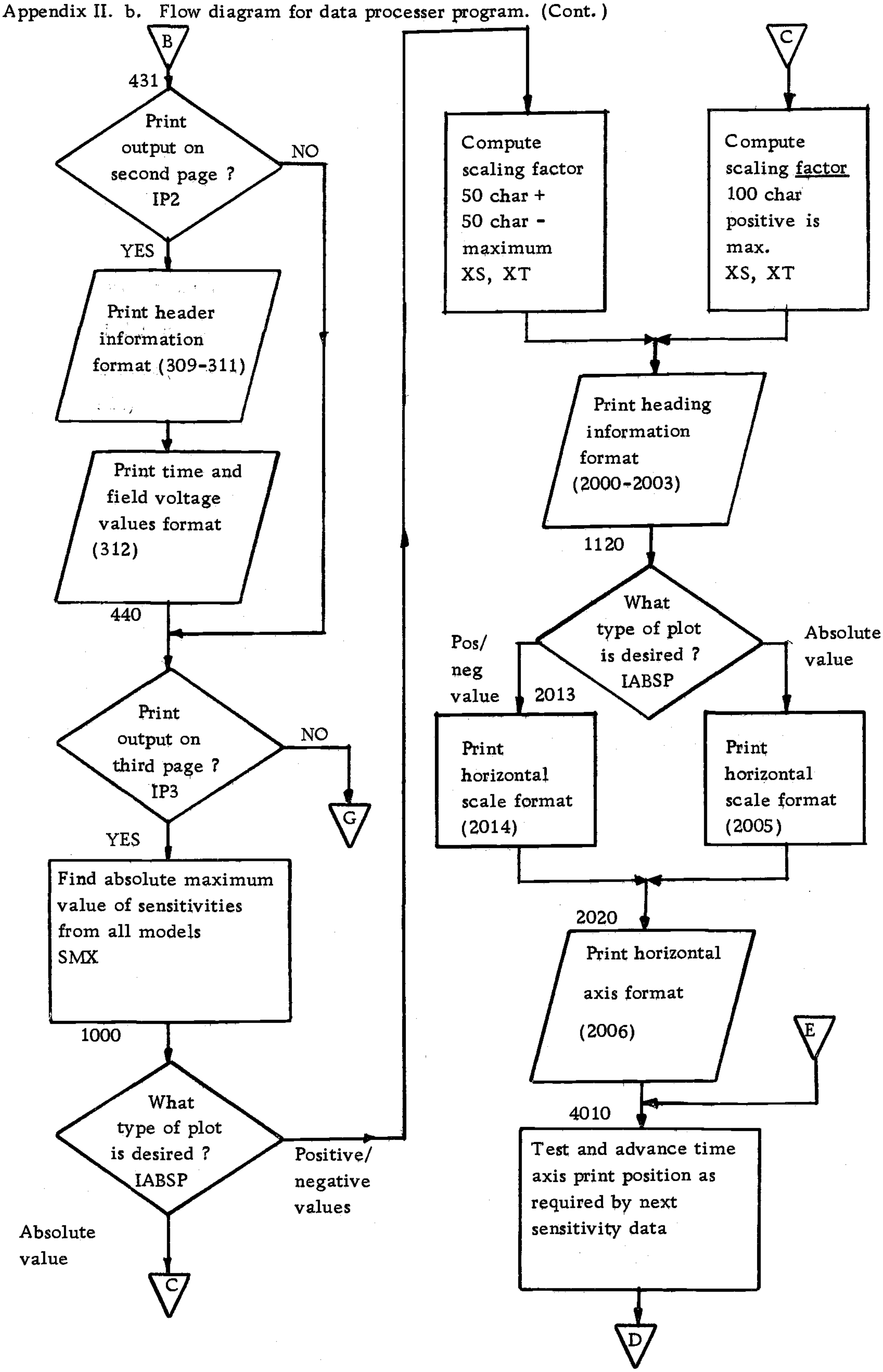
Appendix II. a. Flow diagram for MIMIC program (Cont.)



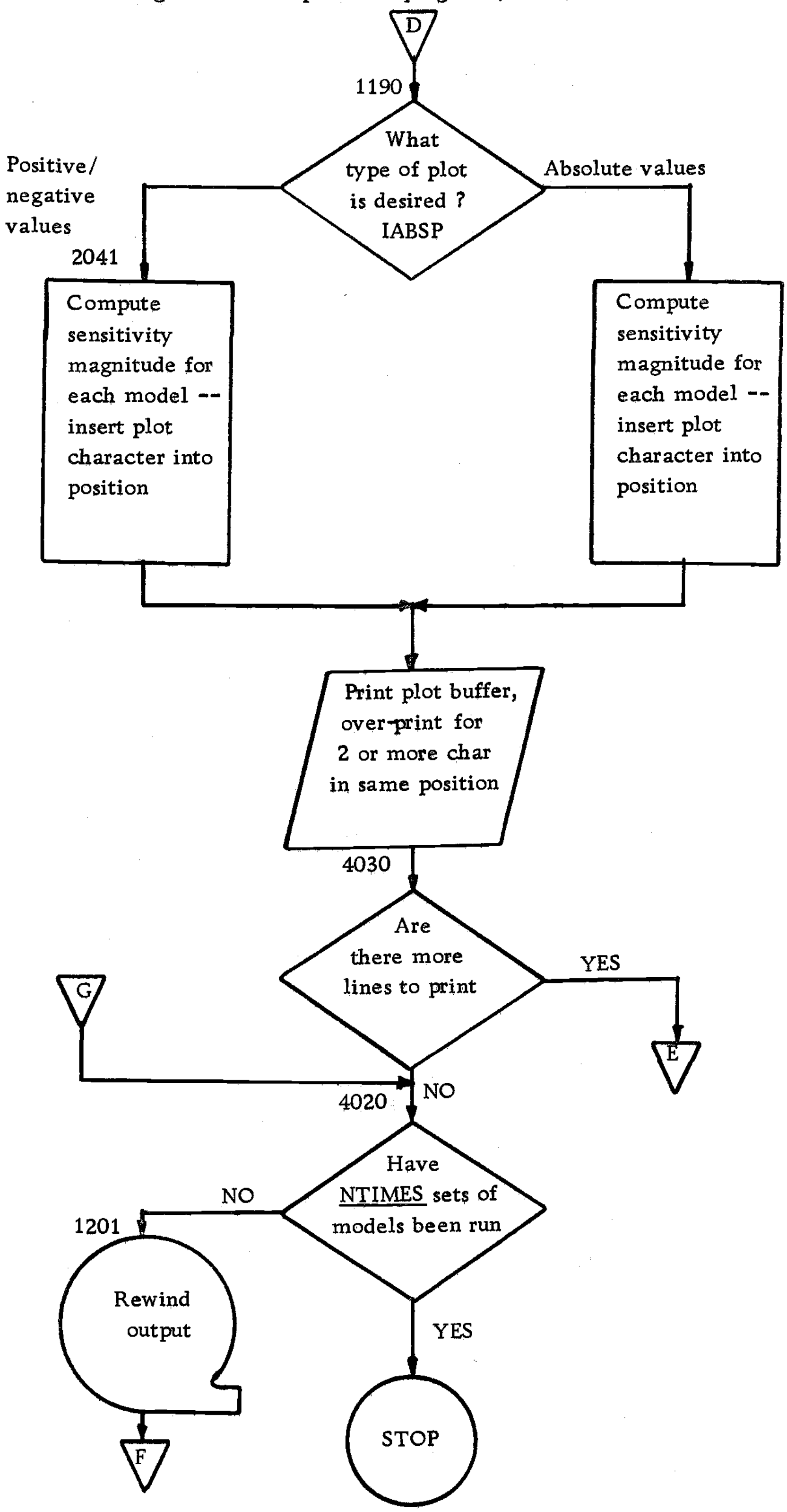
Appendix II. b. Flow diagram for data processer program.



Appendix II. b. Flow diagram for data processer program. (Cont.)



Appendix II. b. Flow diagram for data processer program (Cont.)



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                    ***MIMIC SOURCE-LANGUAGE PROGRAM***

ANALOG - MODELED EXCITER SIMULATOR
*
MODEL SPECIFICATION        INPUT PARAMETERS
*
IDNO   -  MODEL IDENTIFICATION NUMBER
EFD0   -  INITIAL FIELD VOLTAGE PRIOR TO DISTURBANCE
DELETC  -  MAGNITUDE OF DISTURBING VOLTAGE AT TERMINAL REFERENCE
SAT1   -  POINT AT 0.75 SE MAX
KA  -  AMPLIDYNE GAIN
TA  -  AMPLIDYNE TIME CONSTANT
TF  -  TIME CONSTANT OF DAMPENING FEEDBACK LOOP
TE  -  TIME CONSTANT OF EXCITER FIELD CIRCUIT
KF  -  GAIN OF DAMPENING FEEDBACK LOOP
*
                  PAR(IDNO,EFD0,DELETC)
                  PAR(KA,TA,SAT1,TF,TE,KF)
*
T0 ALLOWS OPERATION AT T=0 ONLY
        T0        FSW(T,FALSE,TRUE,FALSE)
*
T2 INHIBITS OPERATION AT T=0 ONLY
        T2        NOT(T0)
*
LOGIC CONTROLS TO SWITCH DT AND DTMAX TO FIT THE CONTROLLING TIME
CONSTANTS SUCH THAT DATA IS OUTPUT APPROXIMATELY 10 TIMES DURING
THE LENGTH OF THAT TIME CONSTANT
*
        TS0       FSW(T-0.185,TRUE,FALSE,FALSE)
        TS11      FSW(T-0.295,TRUE,FALSE,FALSE)
        TS22      FSW(T-1.0,TRUE,FALSE,FALSE)
        TS33      FSW(T-3.0,TRUE,FALSE,FALSE)
        TS0N      NOT(TS0)
        TS11N     NOT(TS11)
        TS22N     NOT(TS22)
        TS1       AND(TS11,TS0N)
        TS2       AND(TS22,TS11N)
        TS3       AND(TS33,TS22N)
        TS4       NOT(TS33)
        TS1N      NOT(TS1)
 TS0    DTMAX     0.19
 TS1    DTMAX     0.005
 TS2    DTMAX     0.05
 TS3    DTMAX     0.2
 TS4    DTMAX     0.5
 T0     DTMIN     0.00001
 TS1    DT        EQL(0.01)
 TS1N   DT        EQL(DTMAX)
*
VOLTAGE REGULATOR CUTS IN AT + OR - 1.0 P.U.
 T0     VRMAX     EQL(1.0)
 T0     VRMIN     NEG(VRMAX)
```

```
 T0       SATE1     EQL(2.250)
 T0       SATE2     EQL(3.00)
 T0       SAT2      EQL(0.388)
*
NO SYSTEM DISTURBANCE AT STAEDY STATE
 T0       DELETR    0.
*
KG  -  SET GAIN OF GENERATOR MODEL SO ET0 = 1.0 P.U.
 T0       KG        1./EFD0
*
ET  -  SET TERMINAL VOLTAGE OF MAIN GENERATOR = 1.0 P.U.
 T0       ET        1.0
*
CALCULATE SATURATION FUNCTION CONSTANTS, C AND K FROM INPUT DATA
 T0       CNUM      LOG((SATE1*SAT2)/(SATE2*SAT1))
 T0       C         CNUM/(SATE2-SATE1)
 T0       K1        LOG(SAT1/SATE1)
 T0       K2        LOG(SAT2/SATE2)
 T0       K3        (SATE2*K1-SATE1*K2)/(SATE2-SATE1)
 T0       K         EXP(K3)
*
INTRODUCE TERMINAL VOLTAGE DISTURBANCE AT 0.195 SECONDS
          T1        FSW(T-0.195,FALSE,TRUE,FALSE)
 T1       DELETR    DELETC
*
RUN EXCITER SYSTEM MODEL, SAVE OUTPUT VALUES AT TIMES DEFINED BY DT
*
          SE        K*EFD*EXP(C*EFD)
*
KE  -  EXCITER FIELD CCT GAIN EQUATED TO SATURATION FUNCTION AT STEADY
STATE OPERATION
 T0       KE        SE
*
          ES        SE*EFD
          EK        KE*EFD
*
E34,E36  -  IMPLICIT DIFFERIENTATION OF FIELD OUTPUT VOLTAGE
          E34       (EFD-E36)*(KF/TF)
          E36       INT(E34/KF,EFD0)
*
          DELET     DELETR+1.0-ET
          EI        DELET-E34
          EA        FTR(KA*EI,TA)
          ER        LIM(EA,VRMIN,VRMAX)
          EE        EK-ES+ER
          EFD       INT(EE/TE,EFD0)
 T2       ET        FTR(KG*EFD,3.0)
*
END OF RUN  TIME = 6 SECONDS
                    FIN(T,6.0)
*
OUTPUT TIME AND FIELD VOLTAGE EXPLICITLY
                    OUT(T,EFD)
                    END
```

```
      PROGRAM  EXCITER SIMULATOR DATA PROCESSER
C
C THIS PROGRAM PROCESSES THE OUTPUT FILE PRODUCED BY THE MIMIC PROGRAM
C  ANALOG - MODELED EXCITER SIMULATOR
C DATA IS READ FROM UNIT 12 (MAG TAPE) IN A FIXED FORMAT VIA MIMIC
C  SENSITIVITY VS TIME IS CALCULATED FOR N MODELS AGAINST A BASE MODEL
C   AND OUTPUT ON PAGE 1  (N .LE. 6  )
C PAGE 2 LISTS THE FIELD VOLTAGE VS TIME AS OUTPUT FROM MIMIC
C THE SENSITIVITY DATA IS NORMALIZED, SCALED AND OUTPUT IN GRAPHIC FORM ON
C  PAGE 3
C  EXTERNAL ROUTINE, IPROSS, CAN BE ANY USER-SUPPLIED ROUTINE WHICH
C   COMPUTES A SPECIFIC ALGORITHIM FOR ARRAY SNTV
      EXTERNAL IPROSS
      COMMON TIME(100,7),EFD(100,7),SNTV(100,6)
      CHARACTER PLOT,BLANK,CHAR
      COMMON/DATA/BLANK(1),CHAR(6)
      DIMENSION PVALUE(6,7),IPRCNT(6,6),ALINE(6)
      DIMENSION RIDNO(7),IDNO(7)
      DIMENSION FILES(7)
      DIMENSION PLOT(104)
      DIMENSION LSAVE(6),JSAVE(6)
      DATA (CHAR=6H+XO*VA)
      DATA (BLANK=4H    )
C  IABSP = 1 FOR ABSOLUTE-VALUED PLOT,  0 FOR STANDARD PLOT
C  IP1 = SET NON-ZERO TO PRINT PAGE 1
C  IP2 = SET NON-ZERO TO PRINT PAGE 2
C  IP3 = SET NON-ZERO TO PRINT PAGE 3
C  IXSUB = DATA PROCESSING SUBPROGRAM TO BE USED
C        = 1  SENSITIVITY USING STANDARD DEFINITION
C             MUST READ IN 1 CARD FOR EACH SENSITIVITY RUN(IMOD-1)
C             SPECIFYING WHICH PARAMETER (1 THRU 6) IS TO BE USED ACCORDIN
C             TO THE STANDARD DEFINITION, PARAMETERS IN SAME ORDER AS INPU
C        = 2  DIFFERENTIAL NORMALIZED VOLTAGE RESPONSE
C        = 3  USER SUPPLIED EXTERNAL ROUTINE
C  IMOD = NUMBER OF MODEL OUTPUTS TO BE PROCESSED (MAX OF 7)
C  RLIM = CUTOFF POINT OF REAL TIME AXIS IN PLOTTING
C  RINC = REAL TIME AXIS INCREMENT
C  ILIM = NUMBER OF TIME VALUES CORRESPONDING TO INPUT DATA (MAX OF 100)
C  NTIMES = NUMBER OF SEPERATE RUNS USING NEW DATA
      READ(60,95)NTIMES
95    FORMAT(I4)
C  READ IN CONTROL PARAMETERS AND ≠IMOD≠ NUMBER OF FILES IN ASCENDING
C     ORDER AS ON TAPE, FIRST MODEL IS CALLED THE NOMINAL CASE
1202  READ(60,99)IMOD,ILIM,RLIM,RINC,IP1,IP2,IP3,IXSUB,IABSP,
     1(FILES(JM),JM=1,IMOD)
99    FORMAT(I2,1X,I4,1X,F5,1X,F5,3(1X,I2),1X,I2,1X,I2,1X,7(F3.,1X))
C  SET UP LOOP CONTROL FOR SUBFILES OF INPUT DATA,ONE FOR EACH MODEL
      DO 7 IT=1,IMOD
C LOCATE START OF SELECTED FILE
1     READ(12,98)IFIL
98    FORMAT(I1)
      IF(EOFCKF(12) .EQ. 1)5,4
C FILE NO. REQUESTED IS NOT ON TAPE OR OUT OF ORDER
5     PRINT 200,FILES(IT)
200   FORMAT(1H1,≠REQUESTED FILE NO. ≠,F3.,≠ NOT FOUND≠)
      STOP
4     IF(IFIL-1)1,8,1
C SKIP NEXT RECORD
8     READ(12,97)
97    FORMAT(1X)
C 3RD RECORD CONTAINS I.D. NUMBER,INITIAL FIELD VOLTAGE, AND STEP DISTURBANCE
      READ(12,101) RIDNO(IT),EFDC,DELETC
101   FORMAT(3(8X,E12.5))
      IF(RIDNO(IT)-FILES(IT))1,3,1
C SKIP 4TH AND 5TH INPUT RECORDS
3     READ(12,104)
C CONVERT FLOATING POINT TO INTEGER I.D. NUMBERS FOR OUTPUT
      IDNO(IT)=RIDNO(IT)
C 6 PARAMETER NAMES INTO ALINE
      READ(12,103) (ALINE(J),J=1,6)
103   FORMAT(11X,A4,5(16X,A4))
C 6 PARAMETER VALUES INTO A ROW OF PVALUE
      READ(12,100) (PVALUE(N,IT),N=1,6)
100   FORMAT(8X,E12.5,5(8X,E12.5))
C SKIP 7TH AND 8TH INPUT RECORDS
      READ(12,104)
104   FORMAT(/)
C  READ VALUES OF TIME AND FIELD VOLTAGE INTO THE ROWS OF TIME AND EFD RESP.
      DO 2 K=1,ILIM
      READ(12,102) TIME(K,IT),EFD(K,IT)
102   FORMAT(8X,E12.5,8X,E12.5)
2     CONTINUE
7     CONTINUE
      INVAR=IMOD-1
C COMPUTE THE PERCENTAGE OF EACH PARAMETER AGAINST ITS RESPECTIVE VALUE
C  IN THE FIRST MODEL
      DO 410 K=1,6
      DO 410 J=2,IMOD
      L=J-1
      IPRCNT(K,L)=((PVALUE(K,J)*100.)/PVALUE(K,1))+0.5
410   CONTINUE
      IF(IXSUB .NE. 2) GO TO 501
C  COMPUTE SENSITIVITY OF THE LAST MODELS AGAINST THE 1ST MODEL
C  IXSUB=2
      DO 400 J=2,IMOD
      K=J-1
      DO 400 I=1,ILIM
      SNTVDY=1.0
      SNTV(I,K)=SNTVDY*(EFD(I,J)-EFD(I,1))/EFD(I,1)
400   CONTINUE
      GO TO 299
501   IF(IXSUB .NE. 1) GO TO 502
C   IXSUB=1
      DO 500 J=2,IMOD
      K=J-1
      READ(60,148) L
148   FORMAT(1X,I3)
      DO 500 I=1,ILIM
```

```
      SNTVDY=(PVALUE(L,J)/(PVALUE(L,J)-PVALUE(L,1)))
      SNTV(I,K)=SNTVDY*(EFD(I,J)-EFD(I,1))/EFD(I,J)
500   CONTINUE
      GO TO 299
C   IXSUB=3
502   CALL IPROSS(IMOD,ILIM)
C  TEST FOR DELETION OF LISTING PAGE 1
299   IF(IP1 .EQ. 0) GO TO 431
C LIST HEADER AND INITIAL VALUE INFORMATION FOR PAGE 1
      PRINT 300
300   FORMAT(1H1,50X,≠SENSITIVITY AND FIELD VOLTAGE DATA≠,/)
      PRINT 301,EFDO,DELETC
301   FORMAT(30X,≠INITIAL FIELD VOLTAGE = ≠,F8.5,≠ P.U. ≠,≠ ---- ≠,
     1≠STEP DISTURBANCE = ≠,F8.5,≠ P.U.≠)
      PRINT 302,ALINE
302   FORMAT(5X,≠VARIABLE PARAMETERS≠,5X,A4,5(14X,A4))
      PRINT 313
313   FORMAT(5X,≠NOMINAL VALUES (PU)≠)
      PRINT 303,IDNO(1),(PVALUE(K,1),K=1,6)
303   FORMAT(7X,≠TEST NO. ≠,I4,4X,F9.5,5(9X,F9.5))
      PRINT 304
304   FORMAT(/,5X,≠PERCENT OF NOMINAL≠,/,5X,≠VALUE FOR TEST≠)
C LIST PARAMETER VARIATIONS FOR EACH MODEL
      DO 420 I=1,INVAR
      PRINT 305,IDNO(I+1),(IPRCNT(K,I),K=1,6)
305   FORMAT(9X,I4,15X,I4,5(14X,I4))
420   CONTINUE
      PRINT 306
306   FORMAT(/,10X,≠TIME≠,40X,≠SENSITIVITY FOR TEST NUMBER≠)
      PRINT 307,(IDNO(KK),KK=2,IMOD)
307   FORMAT(11X,≠SEC≠,12X,I4,5(14X,I4))
C LIST TIME AND CORRESPONDING SENSITIVITY
      DO 430 I=1,ILIM
      PRINT 308,TIME(I,1),(SNTV(I,J),J=1,INVAR)
308   FORMAT(8X,F6.2,10X,F10.5,5(8X,F10.5))
430   CONTINUE
C  TEST FOR DELETION OF LISTING PAGE 2
431   IF(IP2 .EQ. 0) GO TO 441
C LIST HEADER INFORMATION FOR PAGE 2
      PRINT 309
309   FORMAT(1H1,45X,≠FIELD VOLTAGE VARIATIONS FOR TEST NUMBER≠,/)
      PRINT 310
310   FORMAT(10X,≠TIME≠,8X,≠NOMINAL≠,30X,≠FIELD VOLTAGE (PU)≠)
      PRINT 311,(IDNO(KK),KK=1,IMOD)
311   FORMAT(11X,≠SEC≠,8X,I4,6(11X,I4))
C LIST TIME AND CORRESPONDING OUTPUT FIELD VOLTAGE
      DO 440 I=1,ILIM
      PRINT 312,TIME(I,1),(EFO(I,J),J=1,IMOD)
312   FORMAT(8X,F6.2,7(6X,F9.5))
440   CONTINUE
C  TEST FOR DELETION OF LISTING PAGE 3
441   IF(IP3 .EQ. 0) GO TO 4020
C  FIND THE MAXIMUM SENSITIVITY (ABSLOUTE VALUE) IN ALL 6 MODELS
      SMX=0.
      DO 1000 I=1,INVAR
      DO 1000 J=1,ILIM
      TEST=ABSF(SNTV(J,I))
      IF(SMX-TEST)1020,1000,1000
1020  SMX=TEST
1000  CONTINUE
C  CALCULATE THE SCALING FACTOR USING THE VALUE OF SMX AND 100 LINE
C     PRINTER CHARACTER POSITIONS AS MAXIMUM PLOT MAGNITUDE
C SCALE FACTOR IS THE LARGEST INTEGER TIMES THE APPROPRIATE POWER OF 10 TO
C  GO INTO MAXIMUM SENSITIVITY 100 TIMES MINIMUM
      STPINC=SMX/100.
C  FOR STANDARD PLOT, INCREASE STEP SIZE BY 2,  ONLY HAVE 50 POSITIONS
      IF(IABSP .EQ. 0) STPINC=2.*STPINC
      ISCAL=0
1060  IF(STPINC-1.0)1040,1050,1050
1040  STPINC=STPINC*10.
      ISCAL=ISCAL-1
      GO TO 1060
1050  IF(STPINC-10.0)1070,1080,1080
1080  STPINC=STPINC/10.0
      ISCAL=ISCAL+1
      GO TO 1060
1070  STPINC=STPINC+1.0
      ISTEP=STPINC
      IF(ISTEP-10)1042,1043,1043
1043  ISTEP=1
      ISCAL=ISCAL+1
1042  IPOW=ISCAL
      XS=ISTEP
      XT=IPOW
      RSTEP=XS*10**XT
C LIST HEADER INFORMATION FOR PAGE 3
      PRINT 2000
2000  FORMAT(1H1,45X,≠SENSITIVITY  VS  TIME PLOT≠,/)
      PRINT 2001
2001  FORMAT(42X,≠TEST≠,12X,≠DATA POINT≠,10X,≠SCALE≠)
      PRINT 2002
2002  FORMAT(41X,≠PLOTTED≠,11X,≠I.D. CHAR≠,8X,≠1 POSITION =≠,/)
C LIST MODEL NUMBER (IDNO), ASSOCIATED PLOTTING CHARACTER AND SCALE
C  FACTOR FOR EACH MODEL
      DO 1120 K=1,INVAR
      PRINT 2003,IDNO(K+1),CHAR(K),ISTEP,IPOW
2003  FORMAT(42X,I4,16X,R1,13X,I2,≠ X 10(≠,I2,≠)≠)
1120  CONTINUE
C LIST SENSITIVITY MAGNITUDE AXIS  (HORIZONTAL)
      IF(IABSP .EQ. 1) GO TO 2013
C  PRINT ABSOLUTE PLOT SCALE HEADING
      PRINT 2005
2005  FORMAT(//,7X,≠TIME≠,9X,≠ 0 ≠,7X,≠ 10≠,7X,≠ 20≠,7X,≠ 30≠,7X,≠ 40≠,
     17X,≠ 50≠,7X,≠ 60≠,7X,≠ 70≠,7X,≠ 80≠,7X,≠ 90≠,7X,≠100≠)
2020  PRINT 2006
2006  FORMAT(20X,104(1H-))
C LIST INDEPENDENT VARIABLE (TIME) AND REFERENCE POINTS FOR SENSITIVITY MAG.
      I=1
```

```
      RTIME=0.
4010  PRINT 2007,RTIME
2007  FORMAT(5X,F6.2,10X,≠.≠,10(9X,≠.≠))
1330  IF(ABSF(TIME(I,1)-RTIME).LT.(0.1*RINC))GO TO 1320
      IF(TIME(I,1)-RTIME)1300,1320,1340
1340  RTIME=RTIME+RINC
      GO TO 4010
1300  I=I+1
      GO TO 1330
C BLANK OUT DATA LINE BUFFER
1320  DO 1190 K=1,104
      PLOT(K)=BLANK
1190  CONTINUE
C INITIALIZE DATA OVERPRINT COUNTER TO 0
      M=0
C SET LOOP CONTROL FOR 1 PASS FOR EACH MODEL
      DO 1110 J=1,INVAR
C CALCULATE NORMALIZED VALUE FOR SENSITIVITY, CONVERT TO INTEGER, CENTER ON
C   VERTICAL AXIS
      IF(IABSP .EQ. 0) GO TO 2041
C   CALCULATE ABSOLUTE VALUE PLOT POSITION
      L=ABSF(SNTV(I,J))/RSTEP+1.5
C IF CHARACTER POSITION IN OUTPUT BUFFER IS NOT BLANK, ADVANCE OVERPRINT
C   COUNT AND SAVE CHARACTER POSITION (L) AND CHARACTER SYMBOL (J).
C   OTHERWISE FILL IN BUFFER WITH PLOT POINT CHARACTER FOR THAT MODEL
2051  IF(PLOT(L) .EQ. BLANK) 1150,1160
1160  M=M+1
      LSAVE(M)=L
      JSAVE(M)=J
      GO TO 1110
1150  PLOT(L)=CHAR(J)
1110  CONTINUE
C   PRINT DATA BUFFER ONCE ALL MODELS HAVE BEEN PROCESSED
      PRINT 2004,PLOT
2004  FORMAT(1H+,20X,104R1)
C ACCOMPLISH OVERPRINTING FOR COINCIDENTAL DATA POINTS IF ANY
      DO 1350 N=1,M
C BLANK OUT DATA LINE BUFFER
      DO 1170 J=1,104
      PLOT(J)=BLANK
1170  CONTINUE
C PICK UP SAVED CHARACTER PLOT DATA (L AND J), INSERT DATA PLOT CHARACTER
C    PRINT OUTPUT DATA BUFFER. IF N POINTS COINCIDE, N OVERPRINTS ARE GIVEN
      I1=LSAVE(N)
      I2=JSAVE(N)
      PLOT(I1)=CHAR(I2)
      PRINT 2004,PLOT
C THIS PROCESS IS REPEATED FOR EACH VALUE OF TIME
1350  CONTINUE
      IF(I-ILIM)4030,4020,4020
4030  IF((RLIM-RTIME).LT.(RINC-0.1*RINC))GO TO 4020
      I=I+1
      RTIME=RTIME+RINC
      GO TO 4010
4020  CONTINUE
C  ARE THERE MORE SYSTEMS TO BE RUN
      NTIMES=NTIMES-1
      IF(NTIMES .EQ. 0)1200,1201
C  YES, REWIND TAPE AND RESTART
1201  REWIND 12
      GO TO 1202
C  PRINT STANDARD PLOT SCALE HEADING
2013  PRINT 2014
2014  FORMAT(//,7X,≠TIME≠,9X,≠-50≠,7X,≠-40≠,7X,≠-30≠,7X,≠-20≠,7X,≠-10≠,
     17X,≠ 0 ≠,7X,≠ 10≠,7X,≠ 20≠,7X,≠ 30≠,7X,≠ 40≠,7X,≠ 50≠)
      GO TO 2020
2041  IVALUE=(SNTV(I,J)/RSTEP)+0.5
      L=51 + IVALUE
      GO TO 2051
C  NO, ALL DONE
1200  CONTINUE
      END

      SUBROUTINE IPROSS(I,J)
      COMMON TIME(100,7),EFD(100,7),SNTV(100,6)
C  INSERT ALGORITHM FOR COMPUTING AN EXPRESSION FROM EFD TO STORE IN
C    SNTV UTLIZING I AS THE LIMIT OF NO. OF MODELS TO BE PROCESSED
C    (MAX. OF 7) AND J AS LIMIT OF NO. OF TIME VALUES TO BE PROCESSED
C    (MAX OF 100)
      RETURN
      END
```

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 1.00000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU) TEST NO. 100.1	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
101.1	110	100	100	100	100	100
102.1	100	110	100	100	100	100
103.1	100	100	110	100	100	100
104.1	100	100	100	110	100	100
105.1	100	100	100	100	110	100
106.1	100	100	100	100	100	110

SENSITIVITY FOR TEST NUMBER

TIME SEC	101.1	102.1	103.1	104.1	105.1	106.1
0	0	0	0	0	0	0
.10	0	0	0	0	0	0
.20	.00099	-0.00088	0	0	-0.00099	0
.21	.00383	-0.00318	0	0	-0.00362	0
.22	.00818	-0.00644	0	0	-0.00754	-0.00011
.23	.01367	-0.01011	0	.00022	-0.01240	-0.00022
.24	.01972	-0.01395	-0.00011	.00032	-0.01806	-0.00054
.25	.02632	-0.01762	-0.00011	.00086	-0.02408	-0.00086
.26	.03292	-0.02092	-0.00021	.00138	-0.03033	-0.00160
.27	.03941	-0.02374	-0.00021	.00211	-0.03650	-0.00254
.28	.04558	-0.02589	-0.00031	.00336	-0.04236	-0.00368
.29	.05114	-0.02748	-0.00042	.00458	-0.04783	-0.00521
.30	.05621	-0.02822	-0.00052	.00631	-0.05271	-0.00704
.31	.06040	-0.02823	-0.00051	.00832	-0.05692	-0.00926
.32	.06375	-0.02764	-0.00061	.01061	-0.06047	-0.01175
.33	.06607	-0.02634	-0.00081	.01307	-0.06328	-0.01463
.34	.06749	-0.02447	-0.00091	.01582	-0.06506	-0.01769
.35	.06803	-0.02203	-0.00100	.01884	-0.06614	-0.02102
.36	.06752	-0.01922	-0.00120	.02193	-0.06633	-0.02463
.37	.06606	-0.01594	-0.00139	.02531	-0.06565	-0.02843
.38	.06377	-0.01231	-0.00149	.02877	-0.06411	-0.03231
.39	.06054	-0.00841	-0.00158	.03222	-0.06182	-0.03629
.40	.05649	-0.00444	-0.00177	.03577	-0.05877	-0.04037
.41	.05180	-0.00020	-0.00187	.03931	-0.05498	-0.04435
.42	.04637	.00403	-0.00197	.04277	-0.05063	-0.04835
.43	.04029	.00824	-0.00206	.04604	-0.04563	-0.05217
.44	.03375	.01245	-0.00216	.04933	-0.03998	-0.05582
.45	.02672	.01646	-0.00216	.05234	-0.03396	-0.05929
.46	.01931	.02029	-0.00226	.05509	-0.02756	-0.06250
.47	.01168	.02393	-0.00236	.05748	-0.02087	-0.06544
.48	.00374	.02729	-0.00236	.05970	-0.01379	-0.06803
.49	-0.00424	.03028	-0.00247	.06147	-0.00671	-0.07014
.50	-0.01236	.03300	-0.00247	.06277	.00059	-0.07199
.55	-0.05250	.03815	-0.00221	.06165	.03855	-0.07171
.60	-0.08304	.03495	-0.00164	.05122	.07089	-0.06071
.65	-0.09699	.02484	-0.00084	.02932	.09089	-0.03853
.70	-0.09155	.01001	.00011	-0.00213	.09498	-0.00778
.75	-0.07043	-0.00595	.00108	-0.03636	.08373	.02525
.80	-0.04118	-0.02038	.00186	-0.06039	.06795	.05573
.85	-0.00231	-0.03060	.00242	-0.08337	.04116	.07865
.90	.02744	-0.03435	.00254	-0.10404	.00431	.08887
.95	.04629	-0.03167	.00232	-0.10793	-0.02623	.08719
1.00	.05382	-0.02407	.00187	-0.09701	-0.04735	.07614
1.05	.05169	-0.01352	.00132	-0.07518	-0.05784	.05887
1.10	.04220	-0.00274	.00066	-0.04782	-0.05876	.03883
1.15	.02896	.00666	.00022	-0.01925	-0.05199	.01951
1.20	.01621	.01339	-0.00022	.00610	-0.04036	.00316
1.25	.00392	.01837	-0.00054	.02585	-0.02652	-0.00893
1.30	-0.00675	.01836	-0.00065	.03796	-0.01373	-0.01700
1.35	-0.01340	.01543	-0.00065	.04498	-0.00109	-0.02017
1.40	-0.01603	.01110	-0.00065	.04479	.00816	-0.01931
1.45	-0.01517	.00643	-0.00044	.03941	.01393	-0.01582
1.50	-0.01212	.00185	-0.00033	.03077	.01622	-0.01124
1.60	-0.00295	-0.00426	0	.00970	.01210	-0.00218
1.70	.00185	-0.00579	.00011	-0.00415	.00491	.00164
1.80	.00360	-0.00360	.00011	-0.00721	-0.00076	.00109
1.90	.00262	-0.00065	0	-0.00349	-0.00295	-0.00098
2.00	.00098	.00120	0	.00174	-0.00251	-0.00240
2.10	-0.00033	.00142	0	.00490	-0.00109	-0.00294
2.20	-0.00054	.00076	0	.00545	.00022	-0.00240
2.30	-0.00033	0	0	.00403	.00065	-0.00185
2.40	0	-0.00033	0	.00218	.00065	-0.00131
2.50	.00022	-0.00033	0	.00087	.00033	-0.00098
2.60	.00022	-0.00022	0	.00022	0	-0.00087
2.70	.00022	0	0	.00022	-0.00011	-0.00076
2.80	0	.00011	0	.00044	-0.00011	-0.00076
2.90	0	0	0	.00054	-0.00011	-0.00065
3.00	-0.00011	0	0	.00054	-0.00011	-0.00065
3.20	0	-0.00011	-0.00011	.00022	0	-0.00033
3.40	0	0	0	.00011	0	-0.00033
3.60	0	-0.00011	-0.00011	-0.00011	-0.00011	-0.00022
3.80	-0.00011	0	0	0	0	-0.00022
4.00	.00011	0	0	0	0	0
4.20	0	0	0	0	0	0
4.40	0	0	0	-0.00011	0	0
4.60	0	0	0	-0.00011	0	0
4.80	0	0	0	-0.00011	0	0
5.00	0	-0.00011	-0.00011	-0.00011	0	-0.00011
5.20	0	0	0	-0.00011	0	0
5.40	0	0	0	0	0	0
5.60	0	-0.00011	-0.00011	-0.00011	-0.00011	-0.00011
5.80	0	0	0	-0.00011	0	0
6.00	0	0	0	0	0	0

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 100.1	FIELD VOLTAGE (PU) 101.1	102.1	103.1	104.1	105.1	106.1
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
.19	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
.20	1.00094	1.00103	1.00086	1.00094	1.00094	1.00085	1.00094
.21	1.00357	1.00392	1.00328	1.00357	1.00357	1.00324	1.00357
.22	1.00759	1.00834	1.00700	1.00759	1.00759	1.00690	1.00758
.23	1.01274	1.01400	1.01181	1.01274	1.01276	1.01160	1.01272
.24	1.01879	1.02062	1.01750	1.01878	1.01882	1.01712	1.01874
.25	1.02550	1.02796	1.02386	1.02549	1.02558	1.02326	1.02542
.26	1.03270	1.03580	1.03074	1.03268	1.03283	1.02986	1.03255
.27	1.04020	1.04394	1.03796	1.04018	1.04040	1.03676	1.03996
.28	1.04784	1.05220	1.04538	1.04781	1.04816	1.04382	1.04749
.29	1.05550	1.06043	1.05287	1.05546	1.05594	1.05093	1.05500
.30	1.06304	1.06850	1.06032	1.06299	1.06365	1.05797	1.06236
.31	1.07036	1.07627	1.06762	1.07031	1.07117	1.06485	1.06946
.32	1.07738	1.08366	1.07468	1.07732	1.07842	1.07149	1.07623
.33	1.08402	1.09057	1.08143	1.08394	1.08531	1.07782	1.08258
.34	1.09021	1.09694	1.08779	1.09012	1.09178	1.08380	1.08846
.35	1.09590	1.10272	1.09371	1.09580	1.09778	1.08935	1.09381
.36	1.10106	1.10786	1.09914	1.10094	1.10326	1.09446	1.09860
.37	1.10565	1.11233	1.10405	1.10551	1.10820	1.09909	1.10280
.38	1.10965	1.11612	1.10841	1.10950	1.11256	1.10322	1.10640
.39	1.11305	1.11921	1.11220	1.11289	1.11632	1.10683	1.10939
.40	1.11585	1.12161	1.11540	1.11567	1.11949	1.10992	1.11177
.41	1.11804	1.12333	1.11802	1.11785	1.12205	1.11248	1.11355
.42	1.11964	1.12438	1.12005	1.11944	1.12401	1.11451	1.11474
.43	1.12066	1.12478	1.12150	1.12045	1.12537	1.11603	1.11537
.44	1.12111	1.12456	1.12238	1.12089	1.12616	1.11705	1.11545
.45	1.12102	1.12375	1.12270	1.12080	1.12638	1.11757	1.11501
.46	1.12042	1.12239	1.12249	1.12019	1.12606	1.11762	1.11409
.47	1.11933	1.12052	1.12177	1.11909	1.12521	1.11721	1.11271
.48	1.11778	1.11816	1.12056	1.11754	1.12388	1.11638	1.11091
.49	1.11581	1.11538	1.11889	1.11556	1.12208	1.11513	1.10874
.50	1.11345	1.11220	1.11680	1.11320	1.11984	1.11351	1.10621
.55	1.09465	1.08945	1.09846	1.09443	1.10082	1.09850	1.08756
.60	1.07301	1.06497	1.07643	1.07285	1.07803	1.07997	1.06712
.65	1.05141	1.04222	1.05379	1.05133	1.05422	1.06017	1.04774
.70	1.03222	1.02370	1.03316	1.03223	1.03202	1.04121	1.03149
.75	1.01694	1.01047	1.01639	1.01704	1.01359	1.02474	1.01928
.80	1.00554	1.00179	1.00368	1.00571	1.00005	1.01179	1.01066
.85	.99842	.99821	.99565	.99864	.99091	1.00217	1.00561
.90	.99576	.99825	.99266	.99599	.98643	.99615	1.00387
.95	.99625	1.00046	.99339	.99646	.98657	.99388	1.00421
1.00	.99862	1.00353	.99644	.99879	.98989	.99434	1.00558
1.05	1.00178	1.00651	1.00055	1.00190	.99498	.99654	1.00717
1.10	1.00494	1.00881	1.00469	1.00500	1.00059	.99960	1.00850
1.15	1.00755	1.01021	1.00816	1.00757	1.00579	1.00281	1.00934
1.20	1.00938	1.01087	1.01061	1.00936	1.00994	1.00569	1.00967
1.25	1.01041	1.01077	1.01210	1.01036	1.01279	1.00798	1.00959
1.30	1.01081	1.01019	1.01250	1.01075	1.01431	1.00955	1.00925
1.35	1.01065	1.00942	1.01207	1.01059	1.01480	1.01055	1.00880
1.40	1.01014	1.00867	1.01116	1.01008	1.01427	1.01089	1.00837
1.45	1.00949	1.00810	1.01008	1.00945	1.01312	1.01077	1.00804
1.50	1.00887	1.00776	1.00904	1.00884	1.01170	1.01036	1.00784
1.60	1.00804	1.00777	1.00765	1.00804	1.00893	1.00915	1.00784
1.70	1.00792	1.00809	1.00739	1.00793	1.00754	1.00837	1.00807
1.80	1.00825	1.00858	1.00792	1.00826	1.00759	1.00818	1.00835
1.90	1.00867	1.00891	1.00861	1.00867	1.00835	1.00840	1.00858
2.00	1.00898	1.00907	1.00909	1.00898	1.00914	1.00875	1.00876
2.10	1.00916	1.00913	1.00929	1.00916	1.00961	1.00906	1.00889
2.20	1.00924	1.00919	1.00931	1.00924	1.00974	1.00926	1.00902
2.30	1.00930	1.00927	1.00930	1.00930	1.00967	1.00936	1.00913
2.40	1.00936	1.00936	1.00933	1.00936	1.00956	1.00942	1.00924
2.50	1.00943	1.00945	1.00940	1.00943	1.00951	1.00946	1.00934
2.60	1.00951	1.00953	1.00949	1.00951	1.00953	1.00951	1.00943
2.70	1.00957	1.00959	1.00957	1.00957	1.00959	1.00956	1.00950
2.80	1.00963	1.00963	1.00964	1.00963	1.00967	1.00962	1.00956
2.90	1.00968	1.00968	1.00968	1.00968	1.00973	1.00967	1.00962
3.00	1.00972	1.00971	1.00972	1.00972	1.00977	1.00971	1.00966
3.20	1.00978	1.00978	1.00977	1.00977	1.00980	1.00978	1.00975
3.40	1.00980	1.00980	1.00980	1.00980	1.00981	1.00980	1.00977
3.60	1.00986	1.00986	1.00985	1.00985	1.00985	1.00985	1.00984
3.80	1.00989	1.00988	1.00989	1.00989	1.00989	1.00989	1.00987
4.00	1.00991	1.00992	1.00991	1.00991	1.00991	1.00991	1.00991
4.20	1.00993	1.00993	1.00993	1.00993	1.00993	1.00993	1.00993
4.40	1.00995	1.00995	1.00995	1.00995	1.00994	1.00995	1.00995
4.60	1.00996	1.00996	1.00996	1.00996	1.00995	1.00996	1.00996
4.80	1.00997	1.00997	1.00997	1.00997	1.00996	1.00997	1.00997
5.00	1.00998	1.00998	1.00997	1.00997	1.00997	1.00998	1.00997
5.20	1.00998	1.00998	1.00998	1.00998	1.00997	1.00998	1.00998
5.40	1.00998	1.00998	1.00998	1.00998	1.00998	1.00998	1.00998
5.60	1.00999	1.00999	1.00998	1.00998	1.00998	1.00998	1.00998
5.80	1.00999	1.00999	1.00999	1.00999	1.00998	1.00999	1.00999
6.00	1.00999	1.00999	1.00999	1.00999	1.00999	1.00999	1.00999

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 1.00000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU)						
TEST NO. 100.1	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
201.1	120	100	100	100	100	100
202.1	100	120	100	100	100	100
203.1	100	100	120	100	100	100
204.1	100	100	100	120	100	100
205.1	100	100	100	100	120	100
206.1	100	100	100	100	100	120

SENSITIVITY FOR TEST NUMBER

TIME SEC	201.1	202.1	203.1	204.1	205.1	206.1
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00019	-0.00015	0	0	-0.00016	0
.21	.00071	-0.00054	0	0	-0.00060	-0.00001
.22	.00149	-0.00108	0	.00001	-0.00125	-0.00001
.23	.00248	-0.00171	0	.00003	-0.00207	-0.00003
.24	.00358	-0.00238	-0.00002	.00006	-0.00301	-0.00009
.25	.00477	-0.00300	-0.00002	.00014	-0.00402	-0.00016
.26	.00597	-0.00359	-0.00003	.00023	-0.00506	-0.00028
.27	.00714	-0.00410	-0.00004	.00037	-0.00609	-0.00045
.28	.00826	-0.00449	-0.00005	.00055	-0.00708	-0.00067
.29	.00926	-0.00478	-0.00008	.00078	-0.00801	-0.00095
.30	.01013	-0.00496	-0.00008	.00106	-0.00884	-0.00128
.31	.01087	-0.00500	-0.00010	.00139	-0.00957	-0.00167
.32	.01143	-0.00493	-0.00013	.00177	-0.01018	-0.00213
.33	.01181	-0.00475	-0.00016	.00220	-0.01066	-0.00263
.34	.01202	-0.00447	-0.00017	.00266	-0.01102	-0.00318
.35	.01204	-0.00408	-0.00020	.00318	-0.01123	-0.00379
.36	.01188	-0.00361	-0.00023	.00371	-0.01131	-0.00442
.37	.01155	-0.00307	-0.00025	.00428	-0.01125	-0.00509
.38	.01106	-0.00245	-0.00028	.00487	-0.01105	-0.00579
.39	.01040	-0.00180	-0.00030	.00547	-0.01073	-0.00649
.40	.00960	-0.00110	-0.00033	.00609	-0.01028	-0.00720
.41	.00866	-0.00037	-0.00035	.00670	-0.00970	-0.00789
.42	.00761	.00038	-0.00037	.00730	-0.00903	-0.00857
.43	.00644	.00112	-0.00039	.00788	-0.00825	-0.00924
.44	.00520	.00186	-0.00040	.00845	-0.00738	-0.00987
.45	.00388	.00260	-0.00041	.00898	-0.00642	-0.01045
.46	.00249	.00329	-0.00043	.00947	-0.00540	-0.01100
.47	.00107	.00397	-0.00044	.00992	-0.00431	-0.01148
.48	-0.00037	.00461	-0.00045	.01032	-0.00317	-0.01190
.49	-0.00183	.00519	-0.00045	.01065	-0.00200	-0.01225
.50	-0.00328	.00572	-0.00046	.01092	-0.00079	-0.01253
.55	-0.01013	.00691	-0.00041	.01090	.00566	-0.01233
.60	-0.01503	.00675	-0.00032	.00952	.01171	-0.01029
.65	-0.01674	.00492	-0.00016	.00596	.01562	-0.00624
.70	-0.01509	.00168	.00002	.00061	.01685	-0.00088
.75	-0.01174	-0.00221	.00021	-0.00561	.01544	.00417
.80	-0.00640	-0.00516	.00035	-0.01081	.01256	.00909
.85	.00011	-0.00688	.00045	-0.01458	.00804	.01319
.90	.00537	-0.00716	.00047	-0.01711	.00228	.01494
.95	.00866	-0.00615	.00043	-0.01779	-0.00329	.01456
1.00	.00980	-0.00424	.00035	-0.01645	-0.00727	.01252
1.05	.00910	-0.00190	.00025	-0.01342	-0.00952	.00949
1.10	.00711	.00039	.00013	-0.00922	-0.01017	.00616
1.15	.00454	.00227	.00004	-0.00452	-0.00947	.00315
1.20	.00196	.00353	-0.00004	-0.00002	-0.00783	.00070
1.25	-0.00019	.00426	-0.00010	.00375	-0.00566	-0.00101
1.30	-0.00173	.00414	-0.00012	.00640	-0.00343	-0.00204
1.35	-0.00249	.00347	-0.00013	.00790	-0.00122	-0.00238
1.40	-0.00256	.00247	-0.00011	.00828	.00067	-0.00222
1.45	-0.00214	.00135	-0.00008	.00767	.00205	-0.00177
1.50	-0.00145	.00029	-0.00005	.00632	.00278	-0.00121
1.60	.00006	-0.00113	0	.00239	.00254	-0.00018
1.70	.00069	-0.00142	.00003	-0.00067	.00142	.00014
1.80	.00057	-0.00114	.00002	-0.00191	.00029	-0.00004
1.90	.00020	-0.00029	.00001	-0.00146	-0.00039	-0.00032
2.00	-0.00005	.00038	0	-0.00032	-0.00054	-0.00048
2.10	-0.00012	.00055	-0.00001	.00071	-0.00039	-0.00050
2.20	-0.00007	.00036	0	.00117	-0.00015	-0.00042
2.30	-0.00001	.00007	-0.00001	.00105	.00003	-0.00033
2.40	.00003	-0.00011	0	.00061	.00010	-0.00026
2.50	.00003	-0.00015	0	.00019	.00010	-0.00022
2.60	.00001	-0.00010	-0.00001	-0.00007	.00005	-0.00020
2.70	.00001	-0.00001	0	-0.00011	.00001	-0.00017
2.80	0	.00003	0	-0.00004	-0.00001	-0.00016
2.90	-0.00001	.00003	0	.00006	-0.00002	-0.00014
3.00	-0.00001	.00001	-0.00001	.00013	-0.00002	-0.00012
3.20	0	-0.00003	-0.00001	.00012	0	-0.00007
3.40	0	.00001	0	0	.00001	-0.00007
3.60	.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00003
3.80	-0.00002	-0.00001	0	.00002	0	-0.00005
4.00	.00002	0	0	0	.00001	0
4.20	-0.00001	0	0	-0.00001	0	-0.00002
4.40	.00001	0	0	-0.00001	0	.00001
4.60	-0.00001	0	0	-0.00001	0	-0.00002
4.80	.00001	0	0	-0.00001	0	.00001
5.00	-0.00001	-0.00001	-0.00001	-0.00002	-0.00001	-0.00002
5.20	.00001	0	0	-0.00001	0	.00001
5.40	0	0	0	0	0	-0.00001
5.60	0	0	-0.00001	-0.00001	0	0
5.80	0	0	-0.00001	-0.00001	0	-0.00001
6.00	0	0	0	-0.00001	0	.00001

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 100.1	FIELD VOLTAGE (PU) 201.1	202.1	203.1	204.1	205.1	206.1
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
.19	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
.20	1.00094	1.00113	1.00079	1.00094	1.00094	1.00078	1.00094
.21	1.00357	1.00428	1.00303	1.00357	1.00357	1.00297	1.00356
.22	1.00759	1.00909	1.00650	1.00759	1.00760	1.00633	1.00758
.23	1.01274	1.01525	1.01101	1.01274	1.01277	1.01064	1.01271
.24	1.01879	1.02244	1.01637	1.01877	1.01885	1.01572	1.01870
.25	1.02550	1.03039	1.02242	1.02548	1.02564	1.02138	1.02534
.26	1.03270	1.03887	1.02899	1.03267	1.03294	1.02747	1.03241
.27	1.04020	1.04763	1.03594	1.04016	1.04058	1.03386	1.03973
.28	1.04784	1.05649	1.04313	1.04779	1.04842	1.04042	1.04714
.29	1.05550	1.06527	1.05045	1.05542	1.05632	1.04705	1.05450
.30	1.06304	1.07381	1.05777	1.06295	1.06417	1.05364	1.06168
.31	1.07036	1.08199	1.06501	1.07025	1.07185	1.06012	1.06857
.32	1.07738	1.08969	1.07207	1.07724	1.07929	1.06641	1.07509
.33	1.08402	1.09682	1.07887	1.08385	1.08640	1.07246	1.08117
.34	1.09021	1.10331	1.08534	1.09002	1.09311	1.07820	1.08674
.35	1.09590	1.10909	1.09143	1.09568	1.09938	1.08359	1.09175
.36	1.10106	1.11414	1.09709	1.10081	1.10514	1.08861	1.09619
.37	1.10565	1.11842	1.10226	1.10537	1.11038	1.09321	1.10002
.38	1.10965	1.12192	1.10693	1.10934	1.11505	1.09739	1.10323
.39	1.11305	1.12463	1.11105	1.11272	1.11914	1.10111	1.10583
.40	1.11585	1.12656	1.11462	1.11548	1.12264	1.10438	1.10782
.41	1.11804	1.12772	1.11763	1.11765	1.12553	1.10719	1.10922
.42	1.11964	1.12816	1.12006	1.11923	1.12781	1.10953	1.11004
.43	1.12066	1.12788	1.12191	1.12022	1.12949	1.11141	1.11030
.44	1.12111	1.12694	1.12320	1.12066	1.13058	1.11284	1.11005
.45	1.12102	1.12537	1.12393	1.12056	1.13109	1.11382	1.10930
.46	1.12042	1.12321	1.12411	1.11994	1.13103	1.11437	1.10810
.47	1.11933	1.12053	1.12377	1.11884	1.13043	1.11451	1.10648
.48	1.11778	1.11737	1.12293	1.11728	1.12931	1.11424	1.10448
.49	1.11581	1.11377	1.12160	1.11531	1.12769	1.11358	1.10214
.50	1.11345	1.10980	1.11982	1.11294	1.12561	1.11257	1.09950
.55	1.09465	1.08356	1.10221	1.09420	1.10658	1.10085	1.08115
.60	1.07301	1.05688	1.08025	1.07267	1.08322	1.08558	1.06197
.65	1.05141	1.03381	1.05658	1.05124	1.05768	1.06783	1.04485
.70	1.03222	1.01664	1.03395	1.03224	1.03285	1.04961	1.03131
.75	1.01694	1.00500	1.01469	1.01715	1.01123	1.03264	1.02118
.80	1.00554	.99910	1.00035	1.00589	.99467	1.01817	1.01468
.85	.99842	.99853	.99155	.99887	.98386	1.00645	1.01159
.90	.99576	1.00111	.98863	.99623	.97872	.99803	1.01064
.95	.99625	1.00488	.99012	.99668	.97853	.99297	1.01076
1.00	.99862	1.00841	.99439	.99897	.98219	.99136	1.01112
1.05	1.00178	1.01090	.99988	1.00203	.98834	.99224	1,01129
1.10	1.00494	1.01209	1.00533	1.00507	.99567	.99472	1.01113
1.15	1.00755	1.01212	1.00984	1.00759	1.00300	.99801	1.01072
1.20	1.00938	1.01136	1.01294	1.00934	1.00936	1.00148	1.01009
1.25	1.01041	1.01022	1.01471	1.01031	1.01420	1.00469	1.00939
1.30	1.01081	1.00906	1.01499	1.01069	1.01728	1.00734	1.00875
1.35	1.01065	1.00813	1.01416	1.01052	1.01863	1.00942	1.00824
1.40	1.01014	1.00755	1.01264	1.01003	1.01850	1.01082	1.00790
1.45	1.00949	1.00733	1.01085	1.00941	1.01723	1.01156	1.00770
1.50	1.00887	1.00741	1.00916	1.00882	1.01525	1.01167	1.00765
1.60	1.00804	1.00810	1.00690	1.00804	1.01045	1.01060	1.00786
1.70	1.00792	1.00862	1.00649	1.00795	1.00724	1.00935	1.00806
1.80	1.00825	1.00882	1.00710	1.00827	1.00632	1.00854	1.00821
1.90	1.00867	1.00887	1.00838	1.00868	1.00720	1.00828	1.00835
2.00	1.00898	1.00893	1.00936	1.00898	1.00866	1.00844	1.00850
2.10	1.00916	1.00904	1.00971	1.00915	1.00988	1.00877	1.00866
2.20	1.00924	1.00917	1.00960	1.00924	1.01042	1.00909	1.00882
2.30	1.00930	1.00929	1.00937	1.00929	1.01036	1.00933	1.00897
2.40	1.00936	1.00939	1.00925	1.00936	1.00998	1.00946	1.00910
2.50	1.00943	1.00946	1.00928	1.00943	1.00962	1.00953	1.00921
2.60	1.00951	1.00952	1.00941	1.00950	1.00944	1.00956	1.00931
2.70	1.00957	1.00958	1.00956	1.00957	1.00946	1.00958	1.00940
2.80	1.00963	1.00963	1.00966	1.00963	1.00959	1.00962	1.00947
2.90	1.00968	1.00967	1.00971	1.00968	1.00974	1.00966	1.00954
3.00	1.00972	1.00971	1.00973	1.00971	1.00985	1.00970	1.00960
3.20	1.00978	1.00978	1.00975	1.00977	1.00990	1.00978	1.00971
3.40	1.00980	1.00980	1.00981	1.00980	1.00980	1.00981	1.00973
3.60	1.00986	1.00987	1.00985	1.00985	1.00985	1.00985	1.00983
3.80	1.00989	1.00987	1.00988	1.00989	1.00991	1.00989	1.00984
4.00	1.00991	1.00993	1.00991	1.00991	1.00991	1.00992	1.00991
4.20	1.00993	1.00992	1.00993	1.00993	1.00992	1.00993	1.00991
4.40	1.00995	1.00996	1.00995	1.00995	1.00994	1.00995	1.00996
4.60	1.00996	1.00995	1.00996	1.00996	1.00995	1.00996	1.00994
4.80	1.00997	1.00998	1.00997	1.00997	1.00996	1.00997	1.00998
5.00	1.00998	1.00997	1.00997	1.00997	1.00996	1.00997	1.00996
5.20	1.00998	1.00999	1.00998	1.00998	1.00997	1.00998	1.00999
5.40	1.00998	1.00998	1.00998	1.00998	1.00998	1.00998	1.00997
5.60	1.00999	1.00999	1.00999	1.00998	1.00998	1.00999	1.00999
5.80	1.00999	1.00999	1.00999	1.00998	1.00998	1.00999	1.00998
6.00	1.00999	1.00999	1.00999	1.00999	1.00998	1.00999	1.01000

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 1.50000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU)						
TEST NO. 300.1	50.00000	.06000	.13800	1.00000	.41700	.06670

PERCENT OF NOMINAL VALUE FOR TEST	KA	TA	SAT1	TF	TE	KF
301.1	110	100	100	100	100	100
302.1	100	110	100	100	100	100
303.1	100	100	110	100	100	100
304.1	100	100	100	110	100	100
305.1	100	100	100	100	110	100
306.1	100	100	100	100	100	110

SENSITIVITY FOR TEST NUMBER

TIME SEC	301.1	302.1	303.1	304.1	305.1	306.1
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00066	-0.00059	0	0	-0.00066	0
.21	.00263	-0.00212	0	0	-0.00234	0
.22	.00547	-0.00431	0	0	-0.00496	-0.00007
.23	.00908	-0.00677	-0.00007	.00007	-0.00830	-0.00015
.24	.01324	-0.00928	-0.00007	.00029	-0.01204	-0.00029
.25	.01764	-0.01177	-0.00007	.00058	-0.01610	-0.00058
.26	.02213	-0.01409	-0.00014	.00093	-0.02028	-0.00108
.27	.02658	-0.01602	-0.00029	.00150	-0.02448	-0.00164
.28	.03090	-0.01751	-0.00036	.00220	-0.02843	-0.00249
.29	.03483	-0.01863	-0.00042	.00318	-0.03220	-0.00354
.30	.03837	-0.01925	-0.00056	.00429	-0.03566	-0.00479
.31	.04145	-0.01944	-0.00070	.00560	-0.03866	-0.00631
.32	.04404	-0.01914	-0.00077	.00718	-0.04116	-0.00796
.33	.04599	-0.01843	-0.00090	.00888	-0.04322	-0.00987
.34	.04738	-0.01732	-0.00104	.01085	-0.04472	-0.01205
.35	.04810	-0.01594	-0.00124	.01287	-0.04574	-0.01442
.36	.04821	-0.01430	-0.00144	.01502	-0.04628	-0.01692
.37	.04786	-0.01227	-0.00151	.01736	-0.04614	-0.01948
.38	.04685	-0.01012	-0.00171	.01977	-0.04560	-0.02224
.39	.04538	-0.00777	-0.00184	.02223	-0.04459	-0.02499
.40	.04340	-0.00537	-0.00204	.02476	-0.04306	-0.02787
.41	.04097	-0.00278	-0.00210	.02728	-0.04114	-0.03069
.42	.03815	-0.00034	-0.00230	.02974	-0.03883	-0.03351
.43	.03495	.00217	-0.00237	.03219	-0.03620	-0.03633
.44	.03143	.00466	-0.00250	.03452	-0.03317	-0.03903
.45	.02765	.00703	-0.00264	.03672	-0.02996	-0.04159
.46	.02367	.00932	-0.00270	.03886	-0.02649	-0.04403
.47	.01956	.01141	-0.00277	.04080	-0.02282	-0.04628
.48	.01525	.01343	-0.00284	.04255	-0.01909	-0.04841
.49	.01094	.01526	-0.00291	.04418	-0.01517	-0.05027
.50	.00663	.01682	-0.00298	.04548	-0.01118	-0.05194
.55	-0.01508	.01999	-0.00293	.04782	.00939	-0.05525
.60	-0.03246	.01893	-0.00268	.04448	.02659	-0.05288
.65	-0.04232	.01475	-0.00208	.03497	.03814	-0.04434
.70	-0.04438	.00734	-0.00140	.02059	.04319	-0.03086
.75	-0.04252	-0.00141	-0.00070	.00352	.04115	-0.01687
.80	-0.03488	-0.00731	0	-0.01421	.03607	-0.00106
.85	-0.02438	-0.01050	.00057	-0.03012	.02832	.01368
.90	-0.01234	-0.01141	.00107	-0.04295	.01924	.02545
.95	-0.00187	-0.01043	.00129	-0.05092	.01056	.03419
1.00	.00461	-0.00815	.00144	-0.05337	.00245	.03813
1.05	.00772	-0.00534	.00130	-0.05149	-0.00383	.03849
1.10	.00838	-0.00239	.00123	-0.04661	-0.00702	.03639
1.15	.00745	.00007	.00116	-0.03980	-0.00811	.03283
1.20	.00579	.00188	.00094	-0.03233	-0.00776	.02876
1.25	.00420	.00304	.00080	-0.02478	-0.00660	.02496
1.30	.00297	.00355	.00073	-0.01795	-0.00530	.02158
1.35	.00211	.00334	.00065	-0.01207	-0.00421	.01863
1.40	.00167	.00276	.00051	-0.00734	-0.00342	.01625
1.45	.00163	.00204	.00051	-0.00364	-0.00284	.01438
1.50	.00182	.00124	.00036	-0.00087	-0.00255	.01271
1.60	.00247	.00036	.00029	.00204	-0.00240	.00974
1.70	.00233	.00007	.00022	.00393	-0.00233	.00633
1.80	.00189	.00022	.00015	.00524	-0.00204	.00393
1.90	.00138	0	.00007	.00604	-0.00175	.00204
2.00	.00116	-0.00007	.00007	.00647	-0.00131	.00051
2.10	.00087	.00007	0	.00654	-0.00109	-0.00080
2.20	.00073	.00022	0	.00640	-0.00073	-0.00167
2.30	.00051	.00022	-0.00007	.00589	-0.00051	-0.00240
2.40	.00036	.00015	-0.00007	.00531	-0.00029	-0.00276
2.50	.00029	.00015	-0.00007	.00465	-0.00015	-0.00291
2.60	.00015	0	-0.00007	.00400	-0.00007	-0.00291
2.70	.00007	-0.00007	-0.00007	.00334	0	-0.00284
2.80	.00007	0	-0.00007	.00291	.00007	-0.00262
2.90	0	-0.00007	-0.00007	.00232	0	-0.00247
3.00	0	0	-0.00007	.00189	.00007	-0.00225
3.20	0	-0.00007	-0.00007	.00116	.00007	-0.00189
3.40	-0.00007	0	-0.00007	.00080	.00015	-0.00138
3.60	.00007	-0.00007	-0.00007	.00029	0	-0.00094
3.80	0	.00007	0	.00015	.00015	-0.00073
4.00	-0.00007	-0.00007	-0.00007	-0.00022	0	-0.00051
4.20	0	0	-0.00007	-0.00022	0	-0.00036
4.40	0	0	-0.00007	-0.00022	0	-0.00015
4.60	.00007	0	0	-0.00022	.00007	-0.00007
4.80	.00007	0	0	-0.00015	.00007	.00007
5.00	0	0	-0.00007	-0.00029	0	0
5.20	.00007	0	-0.00007	-0.00022	0	.00007
5.40	0	-0.00007	-0.00007	-0.00022	-0.00007	.00007
5.60	0	0	-0.00007	-0.00015	0	0
5.80	0	0	0	-0.00015	0	.00007
6.00	.00007	0	-0.00007	-0.00007	0	.00007

FIELO VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 300.1	301.1	302.1	303.1	304.1	305.1	306.1
		FIELO VOLTAGE (PU)					
0	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000
.19	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000
.20	1.50094	1.50103	1.50086	1.50094	1.50094	1.50085	1.50094
.21	1.50356	1.50392	1.50327	1.50356	1.50356	1.50324	1.50356
.22	1.50758	1.50833	1.50699	1.50758	1.50758	1.50690	1.50757
.23	1.51272	1.51397	1.51179	1.51271	1.51273	1.51158	1.51270
.24	1.51874	1.52057	1.51746	1.51873	1.51878	1.51708	1.51870
.25	1.52543	1.52788	1.52380	1.52542	1.52551	1.52320	1.52535
.26	1.53260	1.53569	1.53064	1.53258	1.53273	1.52978	1.53245
.27	1.54007	1.54380	1.53783	1.54003	1.54028	1.53665	1.53984
.28	1.54769	1.55205	1.54523	1.54764	1.54800	1.54376	1.54734
.29	1.55533	1.56027	1.55270	1.55527	1.55578	1.55079	1.55483
.30	1.56288	1.56835	1.56015	1.56280	1.56349	1.55783	1.56220
.31	1.57023	1.57617	1.56746	1.57013	1.57103	1.56473	1.56933
.32	1.57730	1.58364	1.57456	1.57719	1.57833	1.57142	1.57616
.33	1.58403	1.59068	1.58138	1.58390	1.58531	1.57783	1.58261
.34	1.59036	1.59724	1.58786	1.59021	1.59193	1.58392	1.58862
.35	1.59625	1.60326	1.59394	1.59607	1.59812	1.58964	1.59416
.36	1.60166	1.60871	1.59958	1.60145	1.60385	1.59495	1.59920
.37	1.60656	1.61358	1.60477	1.60634	1.60910	1.59985	1.60372
.38	1.61095	1.61784	1.60947	1.61070	1.61385	1.60430	1.60770
.39	1.61481	1.62150	1.61367	1.61454	1.61808	1.60829	1.61115
.40	1.61815	1.62456	1.61736	1.61785	1.62180	1.61184	1.61406
.41	1.62096	1.62702	1.62055	1.62065	1.62499	1.61492	1.61645
.42	1.62327	1.62892	1.62322	1.62293	1.62767	1.61756	1.61834
.43	1.62508	1.63026	1.62540	1.62473	1.62985	1.61975	1.61973
.44	1.62641	1.63107	1.62710	1.62604	1.63153	1.62152	1.62066
.45	1.62729	1.63139	1.62833	1.62690	1.63274	1.62287	1.62116
.46	1.62773	1.63124	1.62911	1.62733	1.63350	1.62382	1.62124
.47	1.62776	1.63066	1.62945	1.62735	1.63382	1.62439	1.62094
.48	1.62741	1.62967	1.62940	1.62699	1.63373	1.62459	1.62028
.49	1.62670	1.62832	1.62896	1.62627	1.63326	1.62446	1.61930
.50	1.62567	1,62665	1.62816	1.62523	1.63242	1.62402	1.61803
.55	1.61465	1,61244	1.61759	1.61422	1.62170	1.61603	1.60658
.60	1.60099	1.59628	1.60375	1.60060	1.60749	1.60487	1.59333
.65	1.58657	1.58049	1.58870	1.58627	1.59163	1.59209	1.58020
.70	1.57284	1.56652	1.57389	1.57264	1.57579	1.57904	1.56844
.75	1.56068	1.55467	1.56048	1.56058	1.56118	1.56654	1.55829
.80	1.55021	1.54531	1.54918	1.55021	1.54821	1,55531	1.55006
.85	1.54170	1.53829	1.54023	1.54178	1.53749	1.54568	1.54362
.90	1.53539	1.53337	1.53350	1.53524	1.52912	1.53778	1.53865
.95	1.53010	1.52984	1.52865	1.53028	1.52305	1.53157	1.53487
1.00	1.52649	1.52713	1.52536	1.52669	1.51912	1.52683	1.53180
1.05	1.52380	1.52487	1.52306	1.52398	1.51670	1.52327	1.52915
1.10	1.52167	1.52283	1.52134	1.52184	1.51525	1.52070	1.52672
1.15	1.51990	1.52093	1.51991	1.52006	1.51442	1.51878	1.52445
1.20	1.51836	1.51916	1.51862	1.51849	1.51391	1.51729	1.52234
1.25	1.51698	1.51756	1.51740	1.51709	1.51357	1.51607	1.52043
1.30	1.51576	1.51617	1.51625	1.51586	1.51329	1.51503	1.51874
1.35	1.51471	1.51500	1.51517	1.51480	1.51305	1.51413	1.51728
1.40	1.51383	1.51406	1.51421	1.51390	1.51282	1.51336	1.51607
1.45	1.51311	1.51333	1.51339	1.51318	1.51261	1.51272	1.51509
1.50	1.51255	1.51280	1.51272	1.51260	1.51243	1.51220	1.51430
1.60	1.51188	1.51222	1.51193	1.51192	1.51216	1.51155	1.51322
1.70	1.51155	1.51187	1.51156	1.51158	1.51209	1.51123	1.51242
1.80	1.51144	1.51170	1.51147	1.51146	1.51216	1,51116	1.51198
1.90	1.51149	1.51168	1.51149	1.51150	1.51232	1.51125	1.51177
2.00	1.51163	1.51179	1.51162	1.51164	1.51252	1.51145	1.51170
2.10	1.51185	1.51197	1.51186	1.51185	1.51275	1.51170	1.51174
2.20	1.51210	1.51220	1.51213	1.51210	1.51298	1.51200	1.51187
2.30	1.51238	1.51245	1.51241	1.51237	1.51319	1.51231	1.51205
2.40	1.51265	1.51270	1.51267	1.51264	1.51338	1,51261	1.51227
2.50	1.51291	1.51295	1.51293	1.51290	1.51355	1.51289	1.51251
2.60	1.51316	1.51318	1.51316	1.51315	1.51371	1.51315	1.51276
2.70	1.51339	1.51340	1.51338	1.51338	1.51385	1.51339	1.51300
2.80	1.51359	1.51360	1.51359	1.51359	1.51399	1.51360	1.51323
2.90	1.51378	1.51378	1.51377	1.51377	1.51410	1.51378	1.51344
3.00	1.51394	1.51394	1.51394	1.51393	1.51420	1.51395	1.51363
3.20	1.51422	1.51422	1.51421	1.51421	1.51438	1.51423	1.51396
3.40	1.51435	1.51434	1.51435	1.51434	1.51446	1.51437	1.51416
3.60	1.51453	1.51454	1.51452	1.51452	1.51457	1.51453	1.51440
3.80	1.51464	1.51464	1.51465	1.51464	1,51466	1.51466	1.51454
4.00	1.51475	1.51474	1.51474	1.51474	1.51472	1.51475	1.51469
4.20	1.51481	1.51481	1.51481	1.51480	1.51478	1.51481	1.51476
4.40	1.51486	1.51486	1.51486	1.51485	1.51483	1,51486	1.51484
4.60	1.51489	1.51490	1.51489	1.51489	1.51486	1.51490	1.51488
4.80	1.51491	1.51492	1.51491	1.51491	1.51489	1.51492	1.51492
5.00	1.51493	1.51493	1.51493	1.51492	1.51489	1.51493	1.51493
5.20	1.51494	1.51495	1.51494	1.51493	1.51491	1.51494	1.51495
5.40	1.51495	1.51495	1.51494	1.51494	1.51492	1.51494	1.51496
5.60	1.51495	1.51495	1.51495	1.51494	1.51493	1.51495	1.51495
5.80	1.51495	1.51495	1.51495	1.51495	1.51493	1.51495	1.51496
6.00	1.51495	1.51496	1.51495	1.51494	1.51494	1,51495	1.51496

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 1.50000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU)						
TEST NO. 400	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
401	120	100	100	100	100	100
402	100	120	100	100	100	100
403	100	100	120	100	100	100
404	100	100	100	120	100	100
405	100	100	100	100	120	100
406	100	100	100	100	100	120

SENSITIVITY FOR TEST NUMBER

TIME SEC	401	402	403	404	405	406
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00076	-0.00060	0	0	-0.00060	0
.21	.00279	-0.00216	-0.00004	0	-0.00240	-0.00004
.22	.00592	-0.00434	-0.00004	.00004	-0.00498	-0.00008
.23	.00982	-0.00687	-0.00004	.00012	-0.00826	-0.00020
.24	.01423	-0.00950	-0.00008	.00032	-0.01199	-0.00040
.25	.01898	-0.01202	-0.00012	.00063	-0.01601	-0.00071
.26	.02375	-0.01440	-0.00016	.00106	-0.02015	-0.00125
.27	.02839	-0.01645	-0.00027	.00164	-0.02433	-0.00199
.28	.03282	-0.01808	-0.00035	.00240	-0.02832	-0.00291
.29	.03689	-0.01932	-0.00046	.00336	-0.03212	-0.00409
.30	.04047	-0.02004	-0.00058	.00457	-0.03554	-0.00546
.35	.04950	-0.01724	-0.00132	.01328	-0.04609	-0.01591
.40	.04318	-0.00665	-0.00212	.02524	-0.04426	-0.03006
.45	.02568	.00616	-0.00273	.03730	-0.03231	-0.04401
.50	.00340	.01665	-0.00307	.04614	-0.01462	-0.05396
.55	-0.01754	.02253	-0.00305	.04957	.00438	-0.05732
.60	-0.03308	.02319	-0.00270	.04646	.02111	-0.05358
.65	-0.04137	.01957	-0.00212	.03723	.03331	-0.04375
.70	-0.04252	.01319	-0.00141	.02327	.04020	-0.02995
.75	-0.03816	.00591	-0.00069	.00664	.04196	-0.01456
.80	-0.03048	-0.00085	0	-0.01046	.03950	.00027
.85	-0.02155	-0.00611	.00058	-0.02602	.03408	.01293
.90	-0.01300	-0.00947	.00098	-0.03859	.02693	.02262
.95	-0.00585	-0.01089	.00122	-0.04728	.01928	.02920
1.00	-0.00051	-0.01068	.00138	-0.05189	.01197	.03290
1.20	.00597	-0.00325	.00115	-0.03899	-0.00614	.02984
1.40	.00392	.00099	.00063	-0.01132	-0.00834	.01909
1.60	.00254	.00091	.00032	.00432	-0.00544	.01062
1.80	.00171	.00036	.00012	.00805	-0.00286	.00460
2.00	.00099	.00020	0	.00698	-0.00135	.00071
2.20	.00056	.00016	-0.00004	.00531	-0.00056	-0.00143
2.40	.00028	.00012	-0.00008	.00396	-0.00012	-0.00242
2.60	.00012	.00004	-0.00008	.00293	.00004	-0.00266
2.80	0	0	-0.00008	.00214	.00012	-0.00254
3.00	0	.00004	-0.00008	.00151	.00016	-0.00214
3.50	0	0	-0.00004	.00048	.00008	-0.00115
4.00	0	0	-0.00004	.00008	.00004	-0.00048

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 400	FIELD VOLTAGE (PU) 401	402	403	404	405	406
0	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000
.19	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000	1.50000
.20	1.50094	1.50113	1.50079	1.50094	1.50094	1.50079	1.50094
.21	1.50357	1.50427	1.50303	1.50356	1.50357	1.50297	1.50356
.22	1.50757	1.50906	1.50648	1.50756	1.50758	1.50632	1.50755
.23	1.51269	1.51517	1.51096	1.51268	1.51272	1.51061	1.51264
.24	1.51868	1.52229	1.51628	1.51866	1.51876	1.51565	1.51858
.25	1.52532	1.53016	1.52227	1.52529	1.52548	1.52126	1.52514
.26	1.53243	1.53852	1.52876	1.53239	1.53270	1.52730	1.53211
.27	1.53984	1.54716	1.53563	1.53977	1.54026	1.53362	1.53933
.28	1.54738	1.55589	1.54273	1.54729	1.54800	1.54011	1.54663
.29	1.55494	1.56456	1.54995	1.55482	1.55581	1.54666	1.55388
.30	1.56239	1.57300	1.55719	1.56224	1.56358	1.55319	1.56097
.35	1.59529	1.60856	1.59072	1.59494	1.59883	1.58313	1.59107
.40	1.61686	1.62858	1.61507	1.61629	1.62369	1.60502	1.60880
.45	1.62595	1.63294	1.62762	1.62521	1.63612	1.61724	1.61411
.50	1.62457	1.62549	1.62909	1.62374	1.63716	1.62062	1.61009
.55	1.61588	1.61117	1.62197	1.61506	1.62934	1.61706	1.60059
.60	1.60307	1.59428	1.60929	1.60235	1.61558	1.60873	1.58888
.65	1.58872	1.57784	1.59392	1.58816	1.59864	1.59759	1.57722
.70	1.57464	1.56356	1.57811	1.57427	1.58077	1.58526	1.56682
.75	1.56191	1.55204	1.56345	1.56173	1.56364	1.57291	1.55813
.80	1.55105	1.54321	1.55083	1.55105	1.54835	1.56133	1.55112
.85	1.54216	1.53664	1.54059	1.54231	1.53550	1.55097	1.54549
.90	1.53511	1.53179	1.53269	1.53536	1.52530	1.54203	1.54092
.95	1.52963	1.52814	1.52686	1.52994	1.51767	1.53456	1.53711
1.00	1.52542	1.52529	1.52271	1.52577	1.51234	1.52847	1.53383
1.20	1.51636	1.51787	1.51554	1.51665	1.50657	1.51481	1.52394
1.40	1.51297	1.51396	1.51322	1.51313	1.51012	1.51087	1.51780
1.60	1.51178	1.51242	1.51201	1.51186	1.51287	1.51041	1.51446
1.80	1.51168	1.51211	1.51177	1.51171	1.51371	1.51096	1.51284
2.00	1.51205	1.51230	1.51210	1.51205	1.51381	1.51171	1.51223
2.20	1.51255	1.51269	1.51259	1.51254	1.51389	1.51241	1.51219
2.40	1.51304	1.51311	1.51307	1.51302	1.51404	1.51301	1.51243
2.60	1.51347	1.51350	1.51348	1.51345	1.51421	1.51348	1.51280
2.80	1.51382	1.51382	1.51382	1.51380	1.51436	1.51385	1.51318
3.00	1.51409	1.51409	1.51410	1.51407	1.51447	1.51413	1.51355
3.50	1.51453	1.51453	1.51453	1.51452	1.51465	1.51455	1.51424
4.00	1.51475	1.51475	1.51475	1.51474	1.51477	1.51476	1.51463
4.50	1.51486	1.51486	1.51486	1.51484	1.51484	1.51486	1.51482
5.00	1.51491	1.51491	1.51491	1.51489	1.51488	1.51491	1.51490
5.50	1.51493	1.51494	1.51493	1.51492	1.51491	1.51493	1.51493
6.00	1.51494	1.51495	1.51494	1.51493	1.51493	1.51494	1.51495

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 2.00000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU) TEST NO. 500	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
501	110	100	100	100	100	100
502	100	110	100	100	100	100
503	100	100	110	100	100	100
504	100	100	100	110	100	100
505	100	100	100	100	110	100
506	100	100	100	100	100	110

SENSITIVITY FOR TEST NUMBER

TIME SEC	501	502	503	504	505	506
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00055	-0.00044	0	0	-0.00044	0
.21	.00198	-0.00159	0	.00005	-0.00176	0
.22	.00405	-0.00323	-0.00005	0	-0.00373	-0.00005
.23	.00677	-0.00503	0	.00011	-0.00612	-0.00011
.24	.00980	-0.00693	-0.00005	.00022	-0.00889	-0.00027
.25	.01308	-0.00875	-0.00005	.00049	-0.01180	-0.00049
.26	.01638	-0.01035	-0.00011	.00081	-0.01480	-0.00081
.27	.01965	-0.01183	-0.00016	.00119	-0.01783	-0.00135
.28	.02279	-0.01291	-0.00021	.00177	-0.02062	-0.00199
.29	.02570	-0.01367	-0.00027	.00252	-0.02329	-0.00279
.30	.02826	-0.01416	-0.00032	.00336	-0.02567	-0.00374
.35	.03561	-0.01184	-0.00074	.00971	-0.03267	-0.01089
.40	.03319	-0.00458	-0.00109	.01833	-0.03077	-0.02058
.45	.02371	.00352	-0.00140	.02680	-0.02236	-0.03037
.50	.01122	.00962	-0.00155	.03302	-0.01077	-0.03775
.55	-0.00073	.01254	-0.00161	.03557	.00078	-0.04124
.60	-0.01001	.01243	-0.00151	.03411	.01020	-0.04051
.65	-0.01567	.01024	-0.00131	.02912	.01661	-0.03622
.70	-0.01806	.00699	-0.00110	.02161	.01988	-0.02946
.75	-0.01792	.00364	-0.00084	.01276	.02060	-0.02147
.80	-0.01618	.00079	-0.00064	.00371	.01941	-0.01342
.85	-0.01368	-0.00122	-0.00043	-0.00463	.01720	-0.00596
.90	-0.01110	-0.00240	-0.00027	-0.01169	.01454	.00037
.95	-0.00883	-0.00283	-0.00016	-0.01729	.01180	.00550
1.00	-0.00692	-0.00284	0	-0.02126	.00937	.00947
1.20	-0.00297	-0.00124	.00027	-0.02509	.00307	.01686
1.40	-0.00136	-0.00054	.00033	-0.01944	.00038	.01737
1.60	-0.00016	-0.00033	.00038	-0.01214	-0.00087	.01520
1.80	.00054	-0.00016	.00027	-0.00572	-0.00147	.01165
2.00	.00082	-0.00005	.00022	-0.00093	-0.00164	.00796
2.20	.00093	0	.00016	.00218	-0.00147	.00464
2.40	.00087	.00005	.00011	.00387	-0.00120	.00202
2.60	.00071	0	0	.00447	-0.00093	.00005
2.80	.00060	.00005	-0.00005	.00436	-0.00065	-0.00120
3.00	.00044	0	-0.00005	.00387	-0.00044	-0.00191
3.50	.00022	0	-0.00011	.00213	-0.00011	-0.00213
4.00	.00011	0	-0.00005	.00076	.00005	-0.00147

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 500	FIELD VOLTAGE (PU) 501	502	503	504	505	506
0	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
.19	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
.20	2.00094	2.00104	2.00086	2.00094	2.00094	2.00086	2.00094
.21	2.00355	2.00391	2.00326	2.00355	2.00356	2.00323	2.00355
.22	2.00754	2.00828	2.00695	2.00753	2.00754	2.00686	2.00753
.23	2.01261	2.01385	2.01169	2.01261	2.01263	2.01149	2.01259
.24	2.01854	2.02034	2.01727	2.01853	2.01858	2.01691	2.01849
.25	2.02510	2.02751	2.02349	2.02509	2.02519	2.02293	2.02501
.26	2.03210	2.03513	2.03019	2.03208	2.03225	2.02937	2.03195
.27	2.03938	2.04363	2.03719	2.03935	2.03960	2.03608	2.03913
.28	2.04677	2.05102	2.04437	2.04673	2.04710	2.04294	2.04640
.29	2.05416	2.05897	2.05161	2.05411	2.05463	2.04982	2.05364
.30	2.06144	2.06675	2.05879	2.06138	2.06207	2.05664	2.06074
.35	2.09348	2.10028	2.09123	2.09334	2.09533	2.08728	2.09141
.40	2.11476	2.12116	2.11388	2.11455	2.11829	2.10886	2.11081
.45	2.12475	2.12934	2.12543	2.12448	2.12994	2.12044	2.11890
.50	2.12569	2.12786	2.12755	2.12539	2.13209	2.12361	2.11842
.55	2.12060	2.12046	2.12302	2.12029	2.12748	2.12075	2.11268
.60	2.11222	2.11030	2.11461	2.11193	2.11879	2.11418	2.10447
.65	2.10257	2.09958	2.10453	2.10232	2.10815	2.10575	2.09567
.70	2.09295	2.08952	2.09428	2.09274	2.09707	2.09674	2.08736
.75	2.08404	2.08065	2.08473	2.08388	2.08646	2.08795	2.07998
.80	2.07611	2.07306	2.07626	2.07599	2.07681	2.07978	2.07358
.85	2.06917	2.06660	2.06894	2.06909	2.06830	2.07241	2.06805
.90	2.06313	2.06105	2.06268	2.06308	2.06094	2.06586	2.06320
.95	2.05784	2.05619	2.05731	2.05781	2.05461	2.06005	2.05887
1.00	2.05316	2.05187	2.05263	2.05316	2.04920	2.05491	2.05493
1.20	2.03874	2.03819	2.03851	2.03879	2.03410	2.03931	2.04187
1.40	2.02910	2.02885	2.02900	2.02916	2.02552	2.02917	2.03231
1.60	2.02292	2.02289	2.02286	2.02299	2.02069	2.02276	2.02572
1.80	2.01925	2.01935	2.01922	2.01930	2.01820	2.01898	2.02139
2.00	2.01727	2.01742	2.01726	2.01731	2.01710	2.01697	2.01873
2.20	2.01639	2.01656	2.01639	2.01642	2.01679	2.01612	2.01724
2.40	2.01619	2.01635	2.01620	2.01621	2.01690	2.01597	2.01656
2.60	2.01639	2.01652	2.01639	2.01639	2.01721	2.01622	2.01640
2.80	2.01678	2.01689	2.01679	2.01677	2.01758	2.01666	2.01656
3.00	2.01725	2.01733	2.01725	2.01724	2.01796	2.01717	2.01690
3.50	2.01835	2.01839	2.01835	2.01833	2.01874	2.01833	2.01796
4.00	2.01909	2.01911	2.01909	2.01908	2.01923	2.01910	2.01882
4.50	2.01949	2.01951	2.01949	2.01948	2.01950	2.01951	2.01936
5.00	2.01968	2.01970	2.01968	2.01967	2.01964	2.01969	2.01963
5.50	2.01975	2.01977	2.01975	2.01974	2.01971	2.01976	2.01975
6.00	2.01977	2.01979	2.01977	2.01977	2.01974	2.01978	2.01979

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 2.00000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU) TEST NO. 500	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
601	120	100	100	100	100	100
602	100	120	100	100	100	100
603	100	100	120	100	100	100
604	100	100	100	120	100	100
605	100	100	100	100	120	100
606	100	100	100	100	100	120

SENSITIVITY FOR TEST NUMBER

TIME SEC	601	602	603	604	605	606
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00057	-0.00045	0	0	-0.00045	0
.21	.00213	-0.00159	0	.00003	-0.00174	0
.22	.00442	-0.00326	-0.00003	.00003	-0.00371	-0.00006
.23	.00735	-0.00510	-0.00003	.00012	-0.00612	-0.00012
.24	.01065	-0.00708	-0.00003	.00024	-0.00890	-0.00030
.25	.01416	-0.00899	-0.00006	.00047	-0.01187	-0.00053
.26	.01775	-0.01074	-0.00009	.00080	-0.01492	-0.00092
.27	.02123	-0.01226	-0.00015	.00121	-0.01797	-0.00147
.28	.02458	-0.01349	-0.00021	.00179	-0.02086	-0.00214
.29	.02765	-0.01438	-0.00023	.00251	-0.02358	-0.00301
.30	.03038	-0.01497	-0.00032	.00337	-0.02608	-0.00406
.35	.03759	-0.01307	-0.00066	.00981	-0.03366	-0.01177
.40	.03411	-0.00571	-0.00102	.01861	-0.03249	-0.02213
.45	.02315	.00294	-0.00127	.02746	-0.02455	-0.03237
.50	.00941	.00981	-0.00141	.03413	-0.01321	-0.03984
.55	-0.00326	.01344	-0.00144	.03717	-0.00150	-0.04309
.60	-0.01255	.01380	-0.00136	.03608	.00845	-0.04185
.65	-0.01774	.01173	-0.00120	.03131	.01560	-0.03695
.70	-0.01933	.00830	-0.00100	.02376	.01972	-0.02973
.75	-0.01837	.00460	-0.00081	.01459	.02120	-0.02150
.80	-0.01594	.00130	-0.00061	.00497	.02071	-0.01338
.85	-0.01302	-0.00110	-0.00041	-0.00409	.01896	-0.00607
.90	-0.01025	-0.00262	-0.00026	-0.01201	.01650	.00003
.95	-0.00794	-0.00330	-0.00015	-0.01837	.01385	.00489
1.00	-0.00617	-0.00333	-0.00003	-0.02300	.01129	.00861
1.20	-0.00283	-0.00147	.00021	-0.02764	.00400	.01588
1.40	-0.00130	-0.00053	.00030	-0.02074	.00062	.01713
1.60	-0.00012	-0.00033	.00033	-0.01207	-0.00098	.01556
1.80	.00053	-0.00021	.00027	-0.00506	-0.00169	.01245
2.00	.00080	-0.00009	.00021	-0.00021	-0.00184	.00894
2.20	.00089	0	.00015	.00271	-0.00170	.00565
2.40	.00083	.00003	.00009	.00410	-0.00137	.00289
2.60	.00068	.00003	0	.00446	-0.00107	.00077
2.80	.00057	.00003	-0.00003	.00425	-0.00074	-0.00068
3.00	.00045	.00003	-0.00006	.00369	-0.00048	-0.00161
3.50	.00024	.00003	-0.00006	.00199	-0.00009	-0.00223
4.00	.00012	0	-0.00006	.00074	.00006	-0.00169

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

FIELD VOLTAGE (PU)

TIME SEC	NOMINAL 500	601	602	603	604	605	606
0	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
.19	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000	2.00000
.20	2.00094	2.00113	2.00079	2.00094	2.00094	2.00079	2.00094
.21	2.00355	2.00426	2.00302	2.00355	2.00356	2.00297	2.00355
.22	2.00754	2.00902	2.00645	2.00753	2.00755	2.00630	2.00752
.23	2.01261	2.01508	2.01090	2.01260	2.01265	2.01056	2.01257
.24	2.01854	2.02213	2.01616	2.01853	2.01862	2.01555	2.01844
.25	2.02510	2.02989	2.02207	2.02508	2.02526	2.02110	2.02492
.26	2.03210	2.03813	2.02847	2.03207	2.03237	2.02706	2.03179
.27	2.03938	2.04662	2.03522	2.03933	2.03979	2.03329	2.03888
.28	2.04677	2.05519	2.04218	2.04670	2.04738	2.03968	2.04604
.29	2.05416	2.06367	2.04925	2.05408	2.05502	2.04612	2.05313
.30	2.06144	2.07193	2.05631	2.06133	2.06260	2.05252	2.06004
.35	2.09348	2.10668	2.08893	2.09325	2.09691	2.08180	2.08938
.40	2.11476	2.12685	2.11275	2.11440	2.12134	2.10357	2.10699
.45	2.12475	2.13298	2.12579	2.12430	2.13452	2.11609	2.11335
.50	2.12569	2.12903	2.12917	2.12519	2.13785	2.12102	2.11167
.55	2.12060	2.11945	2.12536	2.12009	2.13382	2.12007	2.10548
.60	2.11222	2.10781	2.11709	2.11174	2.12500	2.11520	2.09759
.65	2.10257	2.09637	2.10669	2.10215	2.11360	2.10805	2.08970
.70	2.09295	2.08623	2.09585	2.09260	2.10127	2.09965	2.08263
.75	2.08404	2.07768	2.08564	2.08376	2.08912	2.09143	2.07660
.80	2.07611	2.07061	2.07656	2.07590	2.07783	2.08330	2.07149
.85	2.06917	2.06469	2.06879	2.06903	2.06776	2.07573	2.06708
.90	2.06313	2.05961	2.06223	2.06304	2.05901	2.06882	2.06314
.95	2.05784	2.05512	2.05671	2.05779	2.05156	2.06260	2.05952
1.00	2.05316	2.05105	2.05202	2.05315	2.04532	2.05703	2.05611
1.20	2.03874	2.03778	2.03824	2.03881	2.02939	2.04010	2.04415
1.40	2.02910	2.02866	2.02892	2.02920	2.02211	2.02931	2.03491
1.60	2.02292	2.02288	2.02281	2.02303	2.01886	2.02259	2.02818
1.80	2.01925	2.01943	2.01918	2.01934	2.01755	2.01868	2.02345
2.00	2.01727	2.01754	2.01724	2.01734	2.01720	2.01665	2.02028
2.20	2.01639	2.01669	2.01639	2.01644	2.01730	2.01582	2.01829
2.40	2.01619	2.01647	2.01620	2.01622	2.01757	2.01573	2.01716
2.60	2.01639	2.01662	2.01640	2.01639	2.01789	2.01603	2.01665
2.80	2.01678	2.01697	2.01679	2.01677	2.01821	2.01653	2.01655
3.00	2.01725	2.01740	2.01726	2.01723	2.01849	2.01709	2.01671
3.50	2.01835	2.01843	2.01836	2.01833	2.01902	2.01832	2.01760
4.00	2.01909	2.01913	2.01909	2.01907	2.01934	2.01911	2.01852
4.50	2.01949	2.01952	2.01949	2.01947	2.01952	2.01952	2.01918
5.00	2.01968	2.01971	2.01968	2.01966	2.01963	2.01970	2.01955
5.50	2.01975	2.01979	2.01975	2.01974	2.01969	2.01976	2.01973
6.00	2.01977	2.01981	2.01977	2.01976	2.01972	2.01978	2.01979

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 2.50000 P.U. ---- STEP DISTURBANCE = .01000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU)						
TEST NO. 700	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
701	110	100	100	100	100	100
702	100	110	100	100	100	100
703	100	100	110	100	100	100
704	100	100	100	110	100	100
705	100	100	100	100	110	100
706	100	100	100	100	100	110

SENSITIVITY FOR TEST NUMBER

TIME SEC	701	702	703	704	705	706
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00040	-0.00035	0	0	-0.00040	0
.21	.00154	-0.00127	0	0	-0.00136	0
.22	.00325	-0.00254	.00004	.00004	-0.00290	-0.00004
.23	.00538	-0.00394	.00004	.00009	-0.00473	-0.00009
.24	.00773	-0.00542	.00009	.00017	-0.00686	-0.00022
.25	.01023	-0.00689	.00013	.00035	-0.00911	-0.00039
.26	.01280	-0.00813	.00017	.00061	-0.01135	-0.00070
.27	.01536	-0.00919	.00026	.00095	-0.01354	-0.00104
.28	.01778	-0.01004	.00035	.00138	-0.01562	-0.00156
.29	.01996	-0.01061	.00043	.00190	-0.01748	-0.00216
.30	.02196	-0.01089	.00060	.00258	-0.01912	-0.00288
.35	.02751	-0.00902	.00136	.00730	-0.02338	-0.00821
.40	.02601	-0.00363	.00224	.01348	-0.02109	-0.01517
.45	.01981	.00193	.00234	.01927	-0.01465	-0.02187
.50	.01209	.00580	.00336	.02328	-0.00686	-0.02671
.55	.00513	.00736	.00345	.02477	.00013	-0.02886
.60	.00008	.00704	.00333	.02374	.00527	-0.02846
.65	-0.00283	.00558	.00300	.02068	.00832	-0.02598
.70	-0.00411	.00377	.00258	.01633	.00957	-0.02233
.75	-0.00425	.00208	.00221	.01149	.00963	-0.01812
.80	-0.00387	.00081	.00183	.00663	.00893	-0.01401
.85	-0.00328	.00009	.00153	.00222	.00796	-0.01024
.90	-0.00286	-0.00030	.00124	-0.00158	.00695	-0.00696
.95	-0.00252	-0.00038	.00098	-0.00470	.00611	-0.00415
1.00	-0.00240	-0.00034	.00081	-0.00720	.00539	-0.00184
1.20	-0.00245	.00004	.00022	-0.01244	.00365	.00469
1.40	-0.00238	-0.00004	-0.00017	-0.01327	.00242	.00833
1.60	-0.00204	-0.00013	-0.00043	-0.01184	.00139	.00991
1.80	-0.00161	-0.00013	-0.00052	-0.00921	.00061	.01002
2.00	-0.00117	-0.00013	-0.00052	-0.00631	.00009	.00913
2.20	-0.00078	-0.00013	-0.00048	-0.00357	-0.00030	.00766
2.40	-0.00044	-0.00009	-0.00039	-0.00122	-0.00052	.00601
2.60	-0.00017	-0.00009	-0.00035	.00052	-0.00065	.00432
2.80	.00009	-0.00004	-0.00022	.00179	-0.00061	.00279
3.00	.00022	-0.00004	-0.00013	.00253	-0.00061	.00144
3.50	.00048	-0.00004	.00004	.00284	-0.00044	-0.00070
4.00	.00052	0	.00013	.00265	-0.00022	-0.00148

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME	NOMINAL	FIELD VOLTAGE (PU)					
SEC	700	701	702	703	704	705	706
0	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000
.19	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000
.20	2.50094	2.50103	2.50086	2.50094	2.50094	2.50085	2.50094
.21	2.50353	2.50388	2.50324	2.50353	2.50353	2.50322	2.50353
.22	2.50746	2.50820	2.50688	2.50747	2.50747	2.50680	2.50745
.23	2.51244	2.51367	2.51154	2.51245	2.51246	2.51136	2.51242
.24	2.51823	2.52000	2.51699	2.51825	2.51827	2.51666	2.51818
.25	2.52460	2.52695	2.52302	2.52463	2.52468	2.52251	2.52451
.26	2.53135	2.53430	2.52948	2.53139	2.53149	2.52874	2.53119
.27	2.53831	2.54186	2.53619	2.53837	2.53853	2.53519	2.53807
.28	2.54535	2.54947	2.54303	2.54543	2.54567	2.54174	2.54499
.29	2.55233	2.55697	2.54987	2.55243	2.55277	2.54828	2.55183
.30	2.55915	2.56427	2.55662	2.55929	2.55975	2.55471	2.55848
.35	2.58854	2.59503	2.58642	2.58836	2.59026	2.58305	2.58661
.40	2.60734	2.61352	2.60648	2.60787	2.61054	2.60235	2.60375
.45	2.61596	2.62068	2.61642	2.61666	2.62055	2.61248	2.61077
.50	2.61709	2.61997	2.61847	2.61789	2.62264	2.61546	2.61075
.55	2.61372	2.61494	2.61547	2.61454	2.61962	2.61375	2.60688
.60	2.60820	2.60822	2.60987	2.60899	2.61384	2.60945	2.60147
.65	2.60205	2.60138	2.60337	2.60276	2.60695	2.60402	2.59592
.70	2.59609	2.59512	2.59698	2.59670	2.59995	2.59835	2.59083
.75	2.59063	2.58963	2.59112	2.59115	2.59334	2.59290	2.58637
.80	2.58574	2.58483	2.58593	2.58617	2.58730	2.58784	2.58245
.85	2.58132	2.58055	2.58134	2.58163	2.58184	2.58319	2.57892
.90	2.57729	2.57662	2.57722	2.57758	2.57692	2.57892	2.57566
.95	2.57353	2.57294	2.57344	2.57376	2.57243	2.57496	2.57256
1.00	2.56999	2.56943	2.56991	2.57018	2.56831	2.57125	2.56956
1.20	2.55741	2.55684	2.55742	2.55746	2.55452	2.55826	2.55850
1.40	2.54717	2.54662	2.54716	2.54713	2.54410	2.54773	2.54910
1.60	2.53914	2.53867	2.53911	2.53904	2.53641	2.53946	2.54143
1.80	2.53304	2.53267	2.53301	2.53292	2.53092	2.53318	2.53535
2.00	2.52856	2.52829	2.52853	2.52844	2.52711	2.52858	2.53066
2.20	2.52541	2.52523	2.52538	2.52530	2.52459	2.52534	2.52717
2.40	2.52329	2.52319	2.52327	2.52320	2.52301	2.52317	2.52467
2.60	2.52199	2.52195	2.52197	2.52191	2.52211	2.52184	2.52298
2.80	2.52127	2.52129	2.52126	2.52122	2.52168	2.52113	2.52191
3.00	2.52099	2.52104	2.52098	2.52096	2.52157	2.52085	2.52132
3.50	2.52134	2.52145	2.52133	2.52135	2.52199	2.52124	2.52118
4.00	2.52223	2.52235	2.52223	2.52226	2.52270	2.52218	2.52189
4.50	2.52305	2.52316	2.52305	2.52309	2.52330	2.52304	2.52273
5.00	2.52363	2.52372	2.52363	2.52367	2.52371	2.52363	2.52340
5.50	2.52396	2.52405	2.52397	2.52400	2.52395	2.52397	2.52384
6.00	2.52413	2.52421	2.52413	2.52416	2.52407	2.52414	2.52408

SENSITIVITY AND FIELD VOLTAGE DATA

INITIAL FIELD VOLTAGE = 2.50000 P.U. ---- STEP DISTURBANCE = .02000 P.U.

VARIABLE PARAMETERS	KA	TA	SAT1	TF	TE	KF
NOMINAL VALUES (PU) TEST NO. 800	50.00000	.06000	.13800	1.00000	.41700	.06670
PERCENT OF NOMINAL VALUE FOR TEST						
801	120	100	100	100	100	100
802	100	120	100	100	100	100
803	100	100	120	100	100	100
804	100	100	100	120	100	100
805	100	100	100	100	120	100
806	100	100	100	100	100	120

SENSITIVITY FOR TEST NUMBER

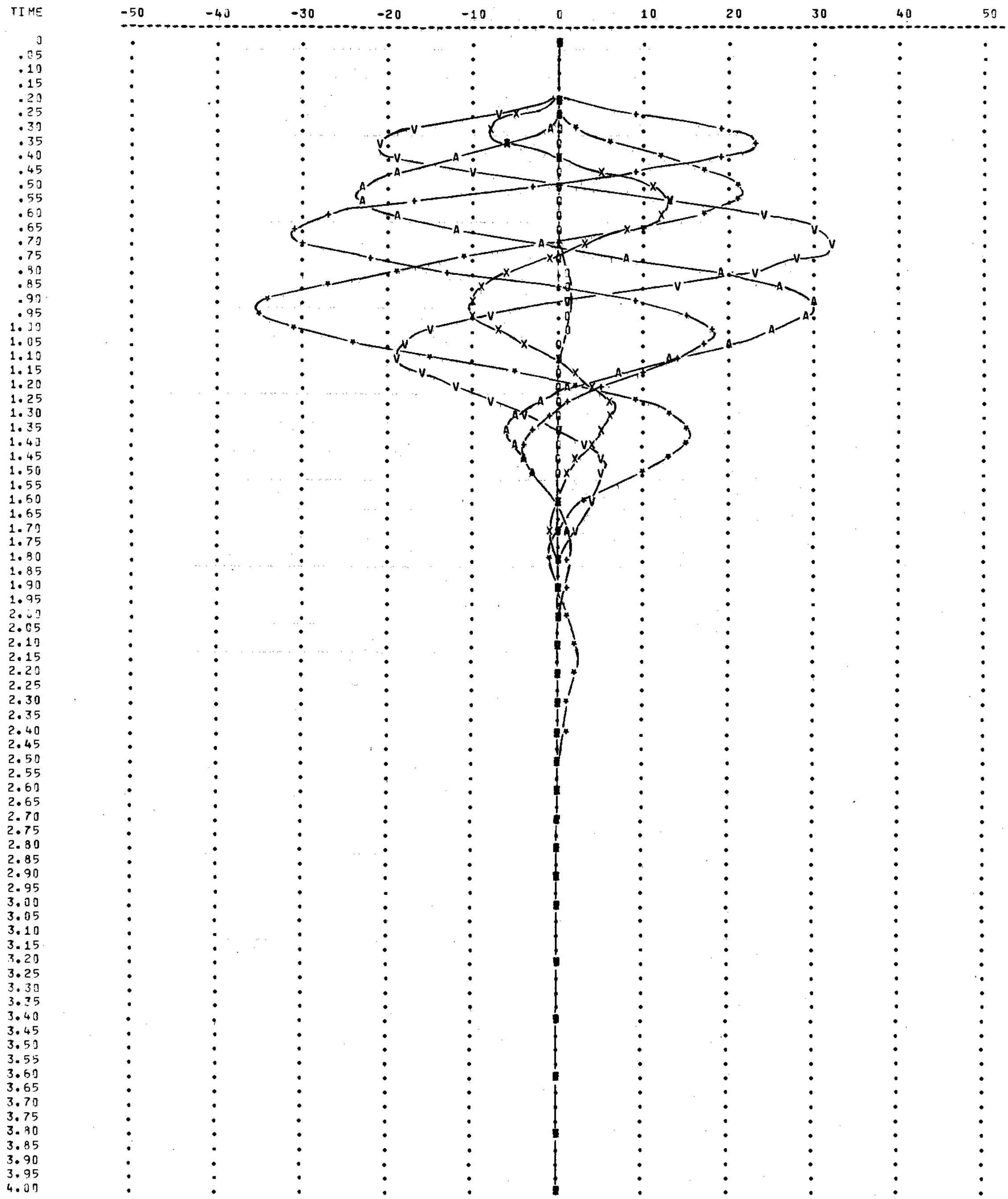
TIME SEC	801	802	803	804	805	806
0	0	0	0	0	0	0
.19	0	0	0	0	0	0
.20	.00089	-0.00072	0	0	-0.00074	0
.21	.00337	-0.00256	.00002	.00002	-0.00278	0
.22	.00703	-0.00511	.00005	.00005	-0.00580	-0.00007
.23	.01155	-0.00804	.00010	.00014	-0.00954	-0.00021
.24	.01663	-0.01107	.00019	.00038	-0.01373	-0.00045
.25	.02137	-0.01397	.00028	.00068	-0.01815	-0.00085
.26	.02736	-0.01658	.00044	.00119	-0.02258	-0.00143
.27	.03256	-0.01880	.00065	.00184	-0.02690	-0.00224
.28	.03745	-0.02054	.00088	.00271	-0.03096	-0.00329
.29	.04184	-0.02178	.00115	.00378	-0.03464	-0.00456
.30	.04569	-0.02248	.00149	.00504	-0.03785	-0.00608
.35	.05516	-0.01892	.00356	.01407	-0.04593	-0.01691
.40	.04989	-0.00829	.00597	.02560	-0.04137	-0.03066
.45	.03614	.00301	.00802	.03635	-0.02893	-0.04333
.50	.02059	.01097	.00928	.04371	-0.01412	-0.05191
.55	.00764	.01438	.00959	.04645	-0.00093	-0.05518
.60	-0.00097	.01402	.00915	.04465	.00877	-0.05358
.65	-0.00541	.01133	.00821	.03919	.01468	-0.04844
.70	-0.00677	.00780	.00739	.03137	.01738	-0.04137
.75	-0.00646	.00450	.00591	.02245	.01780	-0.03377
.80	-0.00551	.00198	.00487	.01348	.01690	-0.02646
.85	-0.00460	.00041	.00397	.00511	.01540	-0.01995
.90	-0.00430	-0.00038	.00321	-0.00219	.01381	-0.01435
.95	-0.00377	-0.00059	.00258	-0.00836	.01231	-0.00956
1.00	-0.00385	-0.00048	.00202	-0.01335	.01105	-0.00548
1.20	-0.00462	.00021	.00041	-0.02433	.00768	.00667
1.40	-0.00463	.00005	-0.00055	-0.02624	.00531	.01430
1.60	-0.00407	-0.00014	-0.00123	-0.02338	.00326	.01823
1.80	-0.00337	-0.00023	-0.00150	-0.01824	.00159	.01920
2.00	-0.00256	-0.00026	-0.00153	-0.01241	.00035	.01817
2.20	-0.00179	-0.00026	-0.00139	-0.00697	-0.00049	.01588
2.40	-0.00106	-0.00021	-0.00115	-0.00240	-0.00099	.01295
2.60	-0.00047	-0.00019	-0.00092	.00101	-0.00127	.00982
2.80	0	-0.00014	-0.00064	.00340	-0.00135	.00681
3.00	.00038	-0.00012	-0.00040	.00479	-0.00130	.00413
3.50	.00090	-0.00005	.00005	.00538	-0.00090	-0.00064
4.00	.00101	-0.00002	.00031	.00386	-0.00047	-0.00271

FIELD VOLTAGE VARIATIONS FOR TEST NUMBER

TIME SEC	NOMINAL 800	801	802	803	804	805	806
		FIELD VOLTAGE (PU)					
0	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000
.19	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000	2.50000
.20	2.50188	2.50225	2.50158	2.50188	2.50188	2.50157	2.50188
.21	2.50706	2.50847	2.50599	2.50707	2.50707	2.50590	2.50706
.22	2.51492	2.51787	2.51278	2.51494	2.51494	2.51249	2.51489
.23	2.52489	2.52976	2.52151	2.52493	2.52495	2.52088	2.52480
.24	2.53645	2.54350	2.53178	2.53653	2.53661	2.53066	2.53626
.25	2.54917	2.55854	2.54325	2.54929	2.54946	2.54148	2.54881
.26	2.56264	2.57438	2.55558	2.56283	2.56315	2.55303	2.56203
.27	2.57652	2.59059	2.56848	2.57681	2.57732	2.56503	2.57557
.28	2.59054	2.60681	2.58170	2.59092	2.59171	2.57724	2.58312
.29	2.60442	2.62271	2.59500	2.60492	2.60606	2.58947	2.60244
.30	2.61796	2.63805	2.60819	2.61861	2.62016	2.60155	2.61531
.35	2.67584	2.70067	2.66743	2.67743	2.68213	2.65551	2.66832
.40	2.71210	2.73484	2.70836	2.71480	2.72372	2.69353	2.69831
.45	2.72799	2.74452	2.72936	2.73164	2.74462	2.71490	2.70843
.50	2.72935	2.73875	2.73435	2.73358	2.74938	2.72294	2.70594
.55	2.72232	2.72579	2.72886	2.72668	2.74356	2.72190	2.69751
.60	2.71153	2.71169	2.71788	2.71567	2.73186	2.71550	2.68753
.65	2.69938	2.69740	2.70494	2.70353	2.71758	2.70645	2.67821
.70	2.68865	2.68562	2.69215	2.69183	2.70278	2.69646	2.67024
.75	2.67850	2.67562	2.68051	2.68114	2.68856	2.68647	2.66351
.80	2.66938	2.66693	2.67026	2.67155	2.67539	2.67692	2.65766
.85	2.66112	2.65908	2.66130	2.66288	2.66339	2.66797	2.65230
.90	2.65350	2.65173	2.65333	2.65492	2.65253	2.65962	2.64717
.95	2.64635	2.64469	2.64609	2.64749	2.64257	2.65179	2.64214
1.00	2.63956	2.63789	2.63935	2.64045	2.63370	2.64443	2.63715
1.20	2.61518	2.61317	2.61527	2.61536	2.60462	2.61853	2.61809
1.40	2.59510	2.59310	2.59512	2.59482	2.58380	2.59740	2.60130
1.60	2.57919	2.57744	2.57913	2.57866	2.56918	2.58359	2.58705
1.80	2.56700	2.56556	2.56690	2.56636	2.55922	2.56768	2.57524
2.00	2.55736	2.55687	2.55785	2.55731	2.55268	2.55811	2.56573
2.20	2.55152	2.55076	2.55141	2.55093	2.54856	2.55131	2.55829
2.40	2.54715	2.54670	2.54706	2.54666	2.54613	2.54673	2.55266
2.60	2.54440	2.54420	2.54432	2.54461	2.54483	2.54386	2.54857
2.80	2.54239	2.54285	2.54279	2.54258	2.54429	2.54228	2.54574
3.00	2.54218	2.54234	2.54213	2.54201	2.54421	2.54163	2.54393
3.50	2.54270	2.54308	2.54268	2.54272	2.54498	2.54232	2.54243
4.00	2.54440	2.54483	2.54439	2.54453	2.54604	2.54420	2.54325
4.50	2.54602	2.54643	2.54602	2.54619	2.54690	2.54596	2.54478
5.00	2.54717	2.54754	2.54718	2.54734	2.54749	2.54718	2.54622
5.50	2.54785	2.54818	2.54736	2.54802	2.54784	2.54739	2.54727
6.00	2.54819	2.54849	2.54820	2.54834	2.54835	2.54823	2.54792

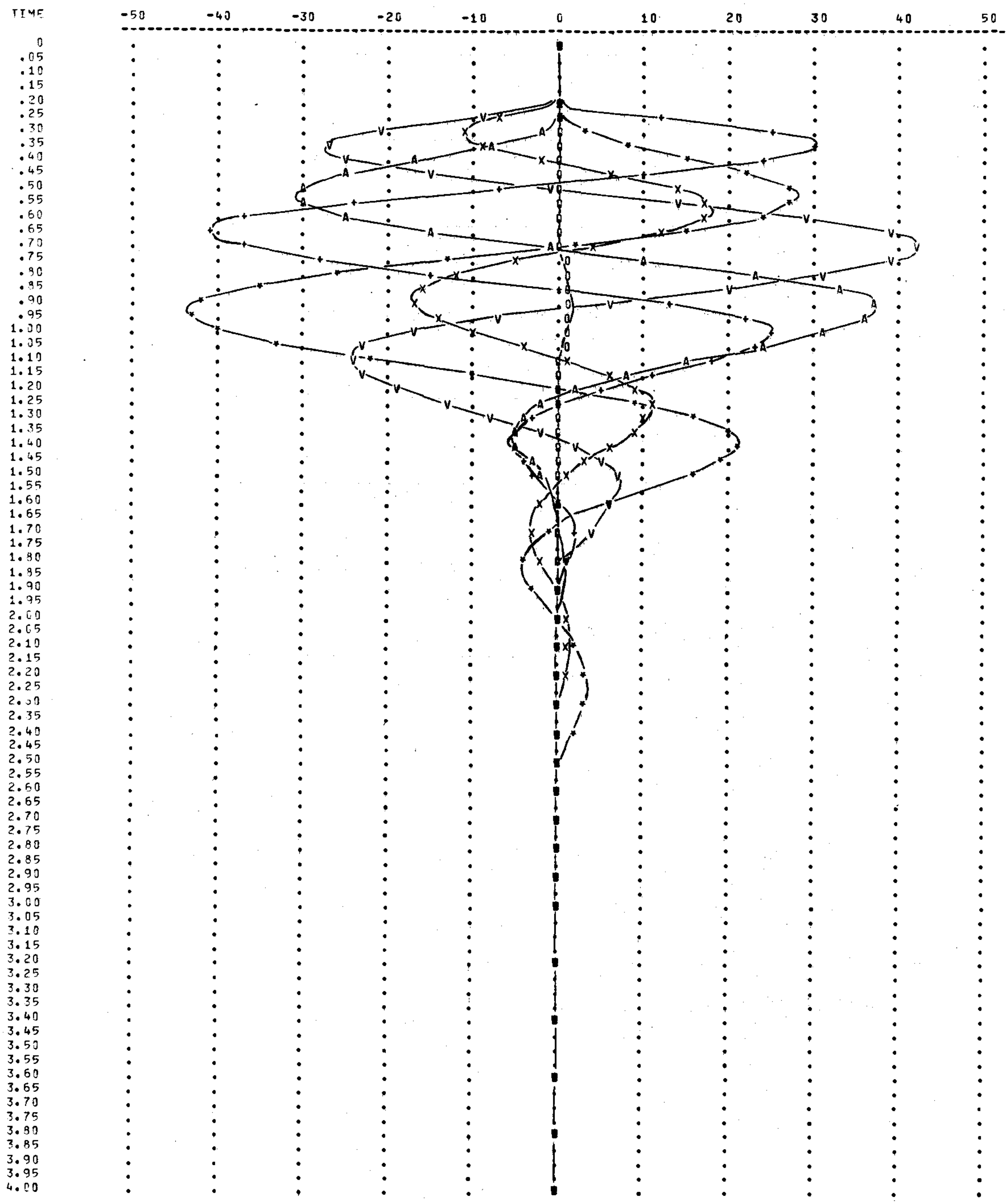
SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
101.1	+	3 X 10(-3)
102.1	X	
103.1	0	
104.1	*	
105.1	V	
106.1	A	



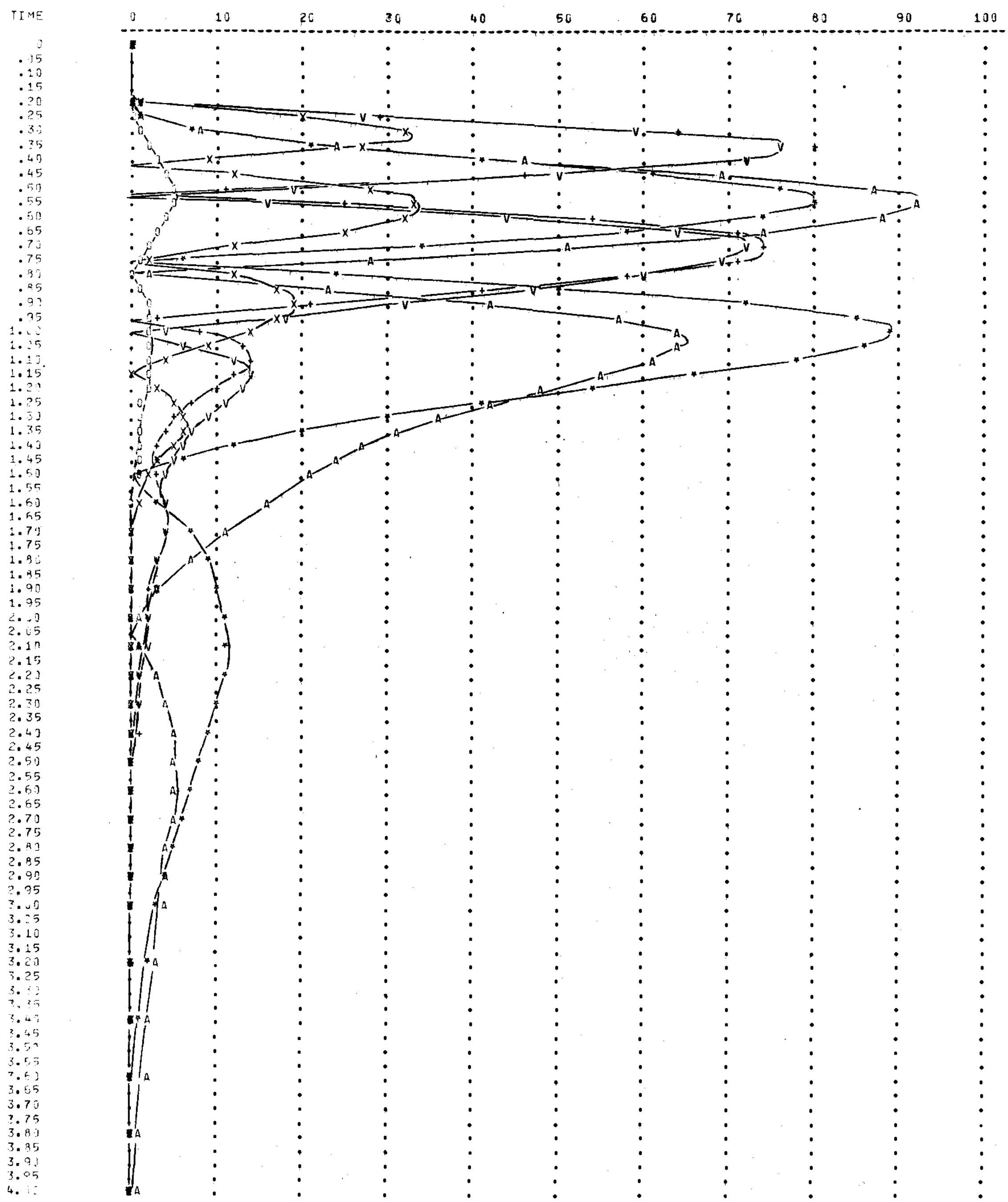
SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
201.1	+	4 X 10(-4)
202.1	X	
203.1	0	
204.1	*	
205.1	V	
206.1	A	



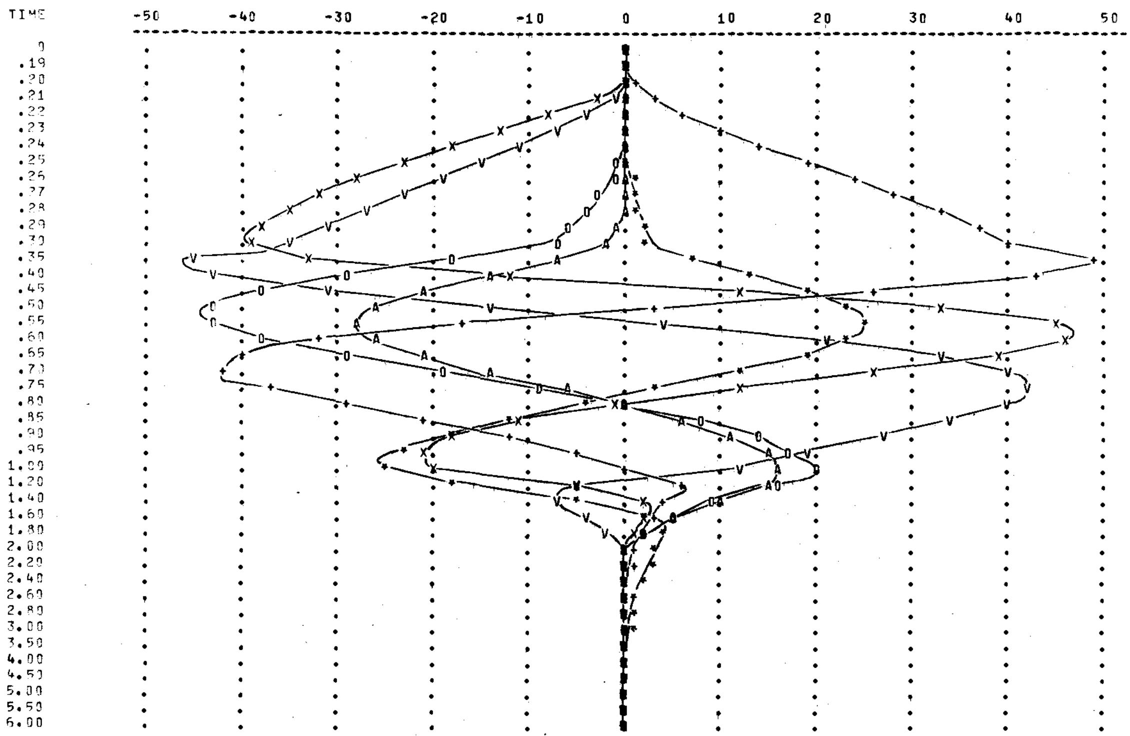
SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
301.1	+	6 X 10(-4)
302.1	X	
303.1	0	
304.1	*	
305.1	V	
306.1	A	



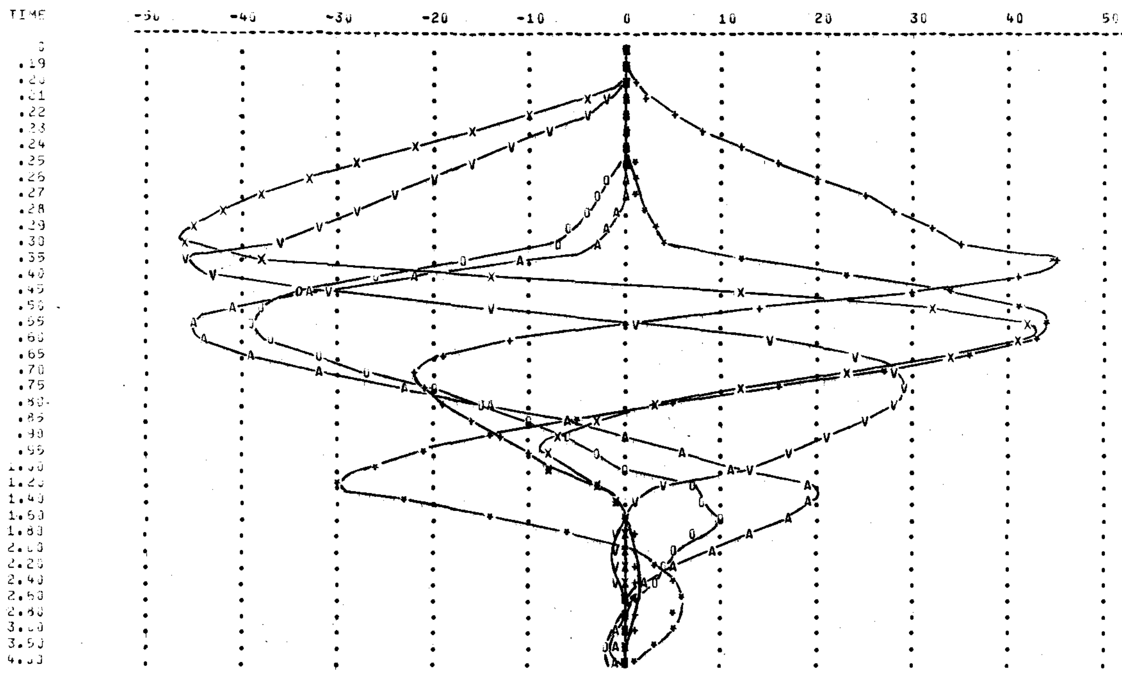
SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
401	+	10 X 10(-4)
402	X	5 X 10(-4)
403	0	7 X 10(-5)
404	*	2 X 10(-3)
405	V	10 X 10(-4)
406	A	2 X 10(-3)

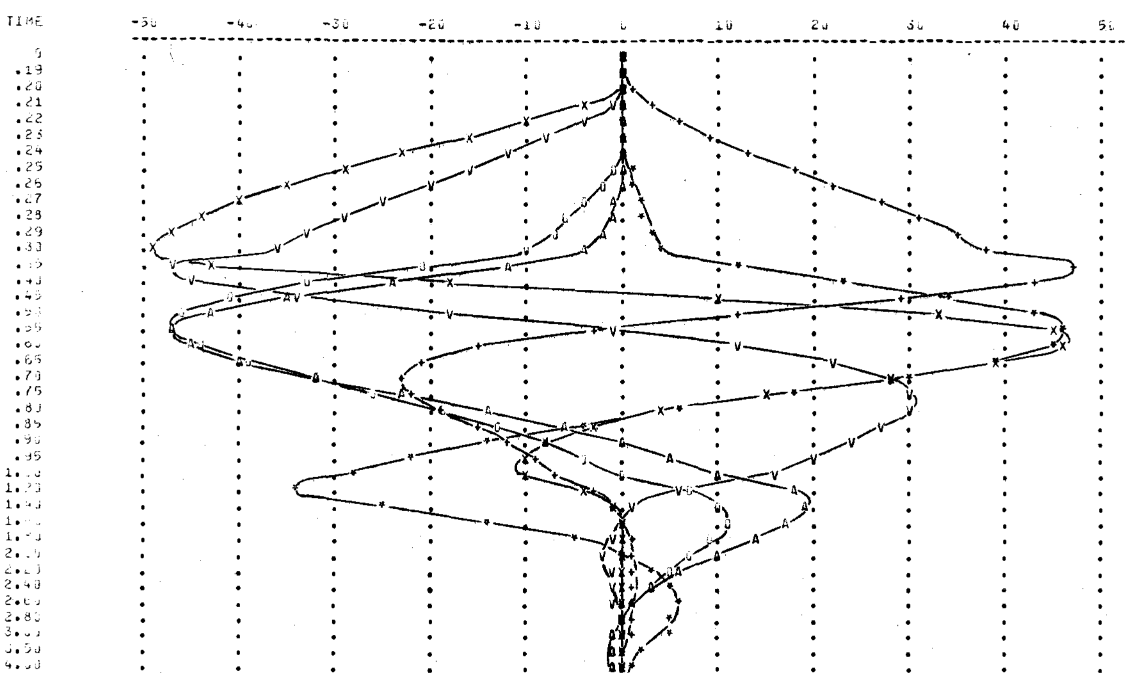


SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
501	+	8 X 10(-4)
502	X	3 X 10(-4)
503	0	4 X 10(-5)
504	*	8 X 10(-4)
505	V	7 X 10(-4)
506	A	9 X 10(-4)

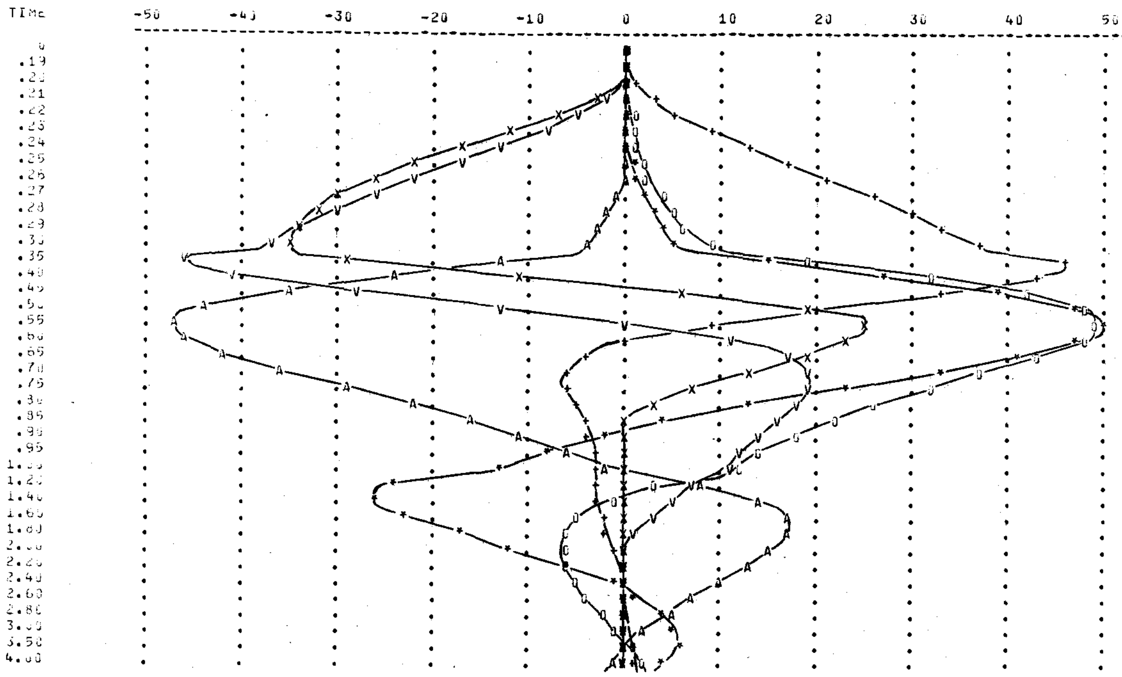


TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
601	+	8 X 10(-4)
602	X	3 X 10(-4)
603	0	3 X 10(-5)
604	*	8 X 10(-4)
605	V	7 X 10(-4)
606	A	9 X 10(-4)



SENSITIVITY VS TIME PLOT

TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
701	+	6 X 10(-4)
702	X	3 X 10(-4)
703	0	7 X 10(-5)
704	*	5 X 10(-4)
705	V	5 X 10(-4)
706	A	6 X 10(-4)



TEST PLOTTED	DATA POINT I.D. CHAR	SCALE 1 POSITION =
801	+	2 X 10(-3)
802	X	5 X 10(-4)
803	0	2 X 10(-4)
804	*	10 X 10(-4)
805	V	10 X 10(-4)
806	A	2 X 10(-3)