APPLICATION OF COMPUTER FOR SOLUTIONS OF ELECTRICAL LOAD-FLOW STUDIES IN ELECTRICAL POWER SYSTEM

(A CASE STUDY OF SHIRORO POWER STATION)

BY
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CERTIFICATION

This is to certify that Amlabu Caleb Akezi carried out the project work presented in this report for the 1996/97 session.

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EXTERNAL EXAMINER DATE

DEDICATION

To my beloved wife Anna and my children Mana, Made and Mafo.

ACKNOWLEDGEMENT

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I am greatly indebted to my wife, Mrs. Anna and children Mana, Made and Mafo for their encouragement, support and understanding throughout the course.

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ABSTRACT

A load study is the determination of the voltage, current and power factor or reactive power at various points on electric network under existing or contemplated conditions of normal operation. Load studies are essential in planning the future development of the system because satisfactory operation of the system depends on knowing the effects of inter-connections with other power system of new loads, new generating stations and new transmission lines before they are installed.

Before the development of large digital computers, load-flow studies were made on calculating boards, which provided small-scale single-phase replicas of actual systems by inter-connecting circuit elements and voltage sources. Setting up the connections, making adjustments and reading the data was tedious and time consuming. Digital computers now provide the solutions of load-flow studies on complex systems.

This project discussed two methods by which load-flow problems can be solved using digital computer. The two methods are the Gauss-Seidel method and the Newton-Raphson method respectively.

The Gauss-Seidel method requires more number of iterations for convergence to take place compare with the Newton-Raphson method

The project also considered how computer can be used to control the output of each plant and each unit within a plant which is a common practice in a power-system operation termed (automatic generation control). By continually monitoring all plant outputs and the power flowing in inter-connections, inter-changing of power with other system is controlled.

The print out of results provided by the computer consist of a number of tabulations. Usually the most important information to be considered first is the table which lists each bus number and name, bus-voltage magnitude in per unit and phase angle, generation and load at each bus in megawatts and megavars. Line charging and megavars of static capacitors or reactors on the bus.

The totals of system generation and loads are listed in megawatts and megavars, the tabulation described is shown in appendix B, being the output of the program.

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CHAPTER ONE

1.1 INTRODUCTION

COMPUTER IN POWER SYSTEMS

The appearance of large digital computer in the 1960s paid the way for unprecedented developments in power system analysis and with them the availability of a more reliable and economic supply of electrical energy with tighter control of the system frequency and voltage levels.

In the early years of this development the mismatch between the size of the problem to be analysed and the limited capability of the computer technology encourage research into algorithmic efficiency. Such efforts have proved invaluable to the development of real time power system control at a time when the utilities are finding it increasingly difficult to maintain high level of reliability at competitive cost.

Fortunately the cost of processing information and computer memory is declining rapidly. By way of example, in less than two decades the cost of computer hardware of similar processing power has reduced by about three hundred times.

The emphasis in modern power systems has turned from resource creation to resource management. The two primary functions of energy management system are security and economy of operation and those tasks are achieved in main control centres. In the present state of the art the results derived by the centre computers are normally presented to the operator who can then accept, modify or ignore the advice received. However, in the longer term the operating commands should be dispatched automatically without human intervention, thus making the task of the computer far more responsible.

The basic power system functions involve very many computer studies requiring processing power capabilities in millions of instructions per second. The most demanding in this respect are the network solutions, the specific task of electrical power system analysis.

In order of increasing processing requirements of electrical energy system are as follows:

(i) Automatic Generation Control (A.G.C.)
(ii) Supervisory Control and Data Acquisition (SCADA)
(iii) Generation Scheduling.
(iv) Network Analysis

1.2 LOAD – FLOW STUDY

A load – flow study is the determination of the voltage, current, power and power factor or reactive power at various points in an electric network under existing or contemplated conditions of normal operation. Load – Flow studies are essential in planning the future development of the system because satisfactory operation of the system depends on knowing the effects of inter connections with other power systems of new loads, new generating stations and new transmission lines before they are installed.

Before the development of large digital computers load flow studies were made on a.c calculating boards which provided small scale single – phase replicas of actual systems by interconnecting circuit elements and voltage sources setting up the connections making adjustments, and read the data was tedious and time consuming.

Digital computers now provide the solution of load – flow studies on complex systems. For instance, the computer program may handle more than 1500 buses, 2500 lines, 500 transformers with tap changing under load and 25 phase – shifting transformers. Complete results are printed quickly and economically.

System planners are interested in studying a power system as it will exist 10 or 20 years in the future.
A power company such as National Electric Power Authority (N.E.P.A) must know far in advance the problems associated with the location of the plant and the best arrangement of lines to transmit the power to load centres which do not exist when the planning must be done.

The principal information obtained from load – flow study is the magnitude and phase angle of the voltage at each bus and real and reactive power flowing in each line. However, much additional information of value is provided by the print out of the solution from computer programs used by the power companies.

Under normal conditions electrical transmission systems operates in their steady – state mode and the basic calculations required to determine the characteristics of this state is termed Load – Flow (or power flow).

The object of load – flow calculations is to determine the steady – state operating characteristics of the power loads.

Loads are normally specified by their constant active and reactive power requirements, assumed unaffected by the small variations of voltage and frequency expected during normal steady – state operation. The solution is expected to provide information of the voltage magnitudes and angles, active and reactive power flows in the individual transmission units, losses and reactive power generated
or absorbed at voltage – controlled buses.

The load – flow problem is formulated in it basic analytical form. The power and voltage constraints make the problem nor linear and the numerical solution must therefore be iterative in nature.

The current problems faced in the development of load flow are an increasing size of systems to be solved, on – line applications for automatic control and system optimization. Hundreds of contributions have been offered in the literature to over come these problems.
Five main properties are required of a load – flow solution method.

(i) High computational speed:- This is especially important when dealing with large systems, real time applications (On – line), multiple case load flow such as in system security assessment and also in iterative applications.
(ii) Low computer storage: important for large systems and in the use of computers with small core storage availability, e.g mini – computer for on line application.
(iii) Reliability of solution:- It is necessary that solution be obtained for ill – conditioned problems
in outage studies and for real time application.
(iv) Versatility:- An ability on the part of load – Flow to handle conventional and special features
(e.g the adjustment of tap ratios on transformer; different representations of power system apparatus),
and its suitability for incorporation into more complicated process.
(v) Simplicity :- The ease of coding a computer program of the load – flow algorithm.

The type of solution required for a load – flow also determines the method used..

Accurate or approximate
Unadjusted or adjusted
Off – line or on – line
Single case or multiple cases

The first practical digital solution method for load – flow were the Y matrix – iterative methods, such as gauss – seidel method. These were suitable because of the low storage requirements, but had the disadvantage of covering slowly or not at all. Z matrix method were developed which over come the reliability problem but storage and speed were sacrificed with large systems. The Newton – Raphson method was developed at this time and was found to have very strong convergence. It was not, however, made competitive until sparsity programming and optionally ordered Gauss – elimination were introduced, which reduced both storage and solution time.

Non linear programming and hybrid methods have also been developed but these have created only academic interest and have not been accepted by industrial users of load – flow. The Newton – Raphson method and technique derived from this agorithm satisfy the requirements of solution type and programming properties better than previously used techniques and gradually replacing them.

1.3 ANALYTICAL DEFINATION

The complete definition of power flow requires knowledge of four variables at each bus K in the system.

P_K —— real or active power
Q_K —— reactive or quadratise power
V_K —— Voltage magnitude
θ_K —— Voltage phase angle.

Only two are known a priori to solve the problem, and the aim of the load – flow is solve the remaining two variables at a bus.

Three different bus conditions are defined based on the steady – state assumptions of constant system frequency and constant voltages where these are controlled.

(i) Voltage controlled bus :- The total injected active power P_K is specified, and the voltage V_K is maintained at a specified value by reactive power injected. This type of bus generally corresponds to either a generator where P_K is fixed by turbine governor setting and V_K is fixed by automatic voltage regulators acting on the machine excitation, or a bus where the voltage is fixed by supplying reactive power from static shunt capacitors or rotating synchronous compesators e.g at substations.

(ii) Non-voltage – controlled bus:- The total injected power $P_K + Q_K$ is specified at this bus. In the physical power system this corresponds to a load centre such as a city or industry, where the consumer demands his power requirements. Both P_K and Q_K are assumed to be unaffected by small variations in bus voltage.

(iii) Slack (swing) bus :- This bus arises because the system losses are not known precisely in advance of the load flow calculation. Therefore the total injected power cannot be specified at every single bus. It is usual to choose one of the variable voltage controlled buses as slack and to regard its active power as unknown. The slack bus voltage is usually assigned as the system phase reference and its complex voltage

$E_S = V_S \angle\theta_S$ is therefore specified.

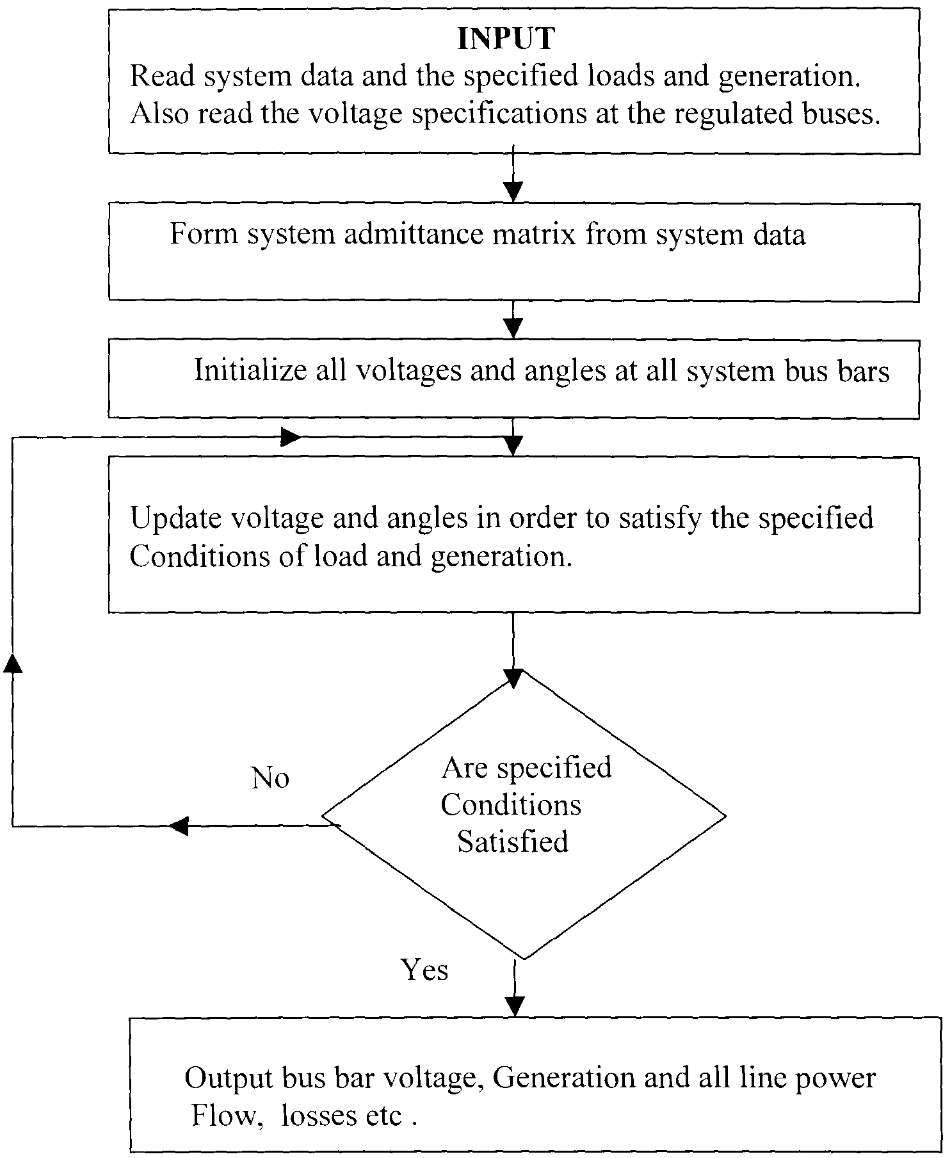
The analogy in a practical power system is the generating station which has the responsibility of system frequency control.

Load – flow solves a set of simultaneous non linear algebraic power equations for the two unknown variables at each mode in a system. A second set of variable equations, which are

linear, are derived from first set and iterative method is applied to this second set.
The basic algorithm which load – flow programs use is depicted in the figure.
System data such as bus bar power conditions network connections and impedance, are read in and the admittance matrix formed. Initial voltages are specified
to all buses; for base case load flows P, Q buses are set to I+j0 while P, V bus bars and angle are set to V+j0.

The interaction cycle is terminated when the bus bar voltages and angles are such that the specified conditions of load and generation are satisfied. This condition is accepted when power mismatches for all buses are less than a small tolerance, n_1 or voltage increments less than n_2.
The typical figures
for n_1 and n_2 are O . 01 P. U and 0. 001 P.U respectively. The sum of the square of the absolute values of power mismatches is a further criterion sometimes used.
When a solution has been reached, complete terminal conditions for all buses are computed.
Line power flows and losses and system total can be calculated.

1.4 <u>Flow Diagram of Basic Load – Flow Algorithm</u>



<u>ITERATION CYCLE</u>

1.4 GAUSS – SEIDER METHOD OF SOLVING LOAD – FLOW

The complexity of obtaining a formal solution for load – flow in power system arises because of the differences in the type of data specified for the different kinds of buses. Although the information of sufficient equations is not difficult , the closed form of solution is not practical. Digital solution of load flow problem considered at this time follow an iterative process by assigning estimated values to the unknown bus voltages and calculating a new value for each bus voltage from the estimated values at the other buses, the real power specified, and the specified reactive power or voltage magnitude. A new set of values for voltage is thus obtained for each bus and used to calculate still another set of bus voltage. Each calculation of a new set of voltages is called an iteration. The iteration process is repeated until the charge at each bus are less than a specified minimum value.

The first to examine is the solution based on expressing the voltage of a bus as a function of the real and the reactive power delivered to a bus from a generator or supplied to the load connected to the bus, the estimated or previously calculated voltage at the other buses and the self and mutual admittance of the node.

The derivation of the fundamental equations starts with a node formulation of the network equations.

The equation for a four bus system will now be derived with the swing bus designated as number 1.Computation start with bus 2. If P_2 and Q_2 are scheduled real and reactive power entering the system at bus2

$$V_2 I_2^* = P_2 + jQ_2 \quad \text{---------------------} \quad 1.1$$

From which I_2 is expressed as $I_2 = \frac{P_2 - jQ_2}{V_2^*}$ --------1.2

And in terms of self and mutual admittance of the nodes with generations and loads omitted since the current into each node is expressed in equation (1.2)

$P_2 - jQ_2 / V_2^* = Y_{21}V_2 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4$ ----------------- (1.3)

Solving for V_2 gives $V_2 = 1/Y_{22}[P_2\text{-}jQ_2 / V_2^* - (Y_{21}V_1 + Y_{23}V_3 + Y_{24}V_4]$. -------- (1.4).

Equation (1.4) gives a corrected value for V_2 based upon scheduled P_2 and Q_2 when the values estimated Originally are substituted for the voltage expressions on the right side of the equation. The calculated value for V_2 and the estimated value for V_2^* will not agree. By substituting the conjugate of the calculated value of V_2 for V_2^* in Eq. (1.4) to calculate another value for V_2 agreement would be reached to a good degree of accuracy after several iterations and would be the correct value for V with the estimated with the voltages without regard to power at the other buses.

The value will not be the solution for V_2 for the specific load – flow conditions however, because the voltages upon which this calculation for V_2 depends are estimated values of voltage at the other buses and the actual voltages are not yet known. Two successive calculations of V_2 (the second being like the first except for the correction of V_2^*) are recommended at each bus before proceeding to the next one.

As the corrected voltage is found at each bus it is used in calculating the corrected voltage at the next. The process is repeated at each bus consecutively throughout the network (except at the swing) to complete the first iteration. Then the entire process is carried out again and again until the amount of correction in voltage at every bus is less than some predetermined precision index.

This process of solving linear algebraic equation is known as Gauss – Seidel iteration method. If the same set of voltage values is used throughout a complete iteration (instead of immediately substituting each new value obtained to calculate the voltage at the next bus), the process is called Gauss – iterative method.

Convergence upon an erroneous solution may occur if the original voltages are widely different from the correct values. Erroneous convergence is usually avoided if the original values are of reasonable magnitude and do not differ too widely in phase. Any unwanted solution is usually detected easily by inspection of the results since the voltage of the system do not normally have a range in phase wider than 45^0 and the difference between near by buses is less than about 10^0 and often very small.

For a total of N buses the calculated voltage at any bus K where P_K and Q_K are given is

$N_K = 1/Y_{KK} (P_K - Q_K / V_K^* - \sum^{N}_{n=1} Y_{kn} V_n)$ ------------ (1.5)

Where $n \neq k$. The values for the voltages on the right side of the equation are the most recently calculated values for the corresponding buses (or the estimated voltage if no iteration has yet been made at that particular bus).

Experience with Gauss – Seidel method of solution of load – flow or power – flow problem has show that an excessive number of iterations are required before the voltage corrections are within acceptable precision index if the corrected voltage at a bus merely replaces the best previous value as the computations proceed from bus to bus. The number of iteration required is reduced considerably if the correction in the voltage at each bus is multiplied by some constant that increases the amount of correction to bring the voltage closer to the value it is approaching. The multipliers that accomplish this improved convergence are called acceleration factors. The difference between the newly calculated voltages and the best previous voltage at the bus is multiplied by the appropriate acceleration factor to obtain a better correction to be added to the previous value. The acceleration factor for real component of the correction may differ from that for the imaginary component. For any system, optimum values for acceleration factor exist, and poor choice of factors may result in less rapid convergence or make convergence impossible.

An acceleration factor of 1.6 for both the real and imaginary components is usually a good advice. Studies may be made to determine the best choice for a particular system.

At a bus where voltage magnitude rather than reactive power is supplied, the real and imaginary components of the voltage for each iteration are found by first computing a value for reactive power from equation (1.5)

$P_K - jQ_K = (Y_{KK}V_K + \sum_{n=1}^{N} Yk_nV_n)\, V_k^*$ -----------(1.6)

Where n = k. If n is allowed to be equal to k

$P_K - jQ_K = VK^* \sum_{n=1}^{N} YknV_n$ ----------(1.7)

$Q_K = \_\ \text{im}\, [V_K^* \sum_{n=1}^{N} Yk_nV_n]$ -------------(1.8)

Where Im means "Imaginary part of"

Reactive power Q_K is evaluated by eq. (1.8) for the best previous voltage values at the buses and this value of QK is substituted in eq. (1.5) to find a new V_K. The components of the new VK are then multiplied by the ratio of the specified constant magnitude of VK to the magnitude of the VK found by equation (1.5). The result is the corrected complex voltage specifies magnitude.

1.5 THE NEWTON – RAPHSON METHOD.

Taylor's series expansion for a function of two or more variables is the basis for the Newton – Raphson method of solving the load – flow problem. The study of the method will begin by discussion of the solution of a problem involving only two equations and two variables. Then it will be seen how to extend the analysis to solution of load – flow equation.

Let consider the equation of a function of two variables X, and X_2 equal to a constant K_1 expressed as

$F_1\,(X_1, X_2) = K_1$ ---------(1.9)

And a second equation $f_2(X_1, X_2) = K_2$ ----------------- (1.10)

Where K_1 and K_2 are constant.

The solutions of these equations will then be estimated to be $X_1^{(0)}$ and $X_2^{(0)}$. The superscripts indicate that these values are initial estimates.

$\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ designated as the values to be added to $X_1^{(0)}$ and $X_2^{(0)}$ to yield the correction solutions. Then it will become

$K_1 = f_1(X_1, X_2) = f_1(X_1^{(0)} + \Delta X_1^{(0)}, X_2^{(0)} + \Delta X_2^{(0)})$ --------1.11

$K_2 = f_2(X_1, X_2) = f_2(X_1^{(0)} + \Delta X_1^{(0)}, X_2^{(0)} + \Delta X_2^{(0)})$ ---------- 1.12

The problem now is to solve for $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$,

Which can be done by expanding equations (1.11) and (1.12) in Taylor's series to give

$$K_1 = f_1(X_1^{(0)}, X_2^{(0)} + \Delta X_1^{(0)}\, \delta f_1/\delta X_1 \Big|_{(0)} \quad \Delta X_2^{(0)}\, \delta f_2/\delta X_2 \Big|_{(0)} + \quad \text{-----------}1.13$$

$$K_2 = f_2(X_1^{(0)}, X_2^{(0)}) + \Delta X_1^{(0)}\, \delta f_2/\delta X_1 \Big|_{(0)} + \Delta X_2^{(0)}\, \delta f_2/\delta X_2 \Big|_{(0)} +. \quad \text{---------}\ 1.14$$

where the partial derivatives of order greater than 1 in the series of terms of expansion haven't been listed. The term $\delta f_1 / \delta X_{1(0)}$ indicates that the partial derivative is evaluated for the value of $X_1^{(0)}$ and $X_2^{(0)}$

Other such terms are evaluated similarly.

If the partial derivative of order greater than 1 is neglected then equations (1.13) and (1.14) can be re-written in matrix forms. They become

$$\begin{Bmatrix} K_1 - f_1(X_1^{(0)}, X_2^{(0)}) \\ K_2 - f_2(X_1^{(0)}, X_2^{(0)}) \end{Bmatrix} = \begin{bmatrix} \delta f_1 \big| \delta X_1 & \delta f_1 \big| \delta X_2 \\ \delta f_2 \big| \delta X_1 & \delta f_2 \big| \delta X_2 \end{bmatrix} \begin{bmatrix} \triangle X_1^{(0)} \\ \triangle X_2^{(0)} \end{bmatrix} \quad \text{------------- } 1.15$$

where the square matrix of partial derivatives is called the jacobian J or in this case $J^{(0)}$ to indicate that the initial estimates $X_1^{(0)}$ and $X_2^{(0)}$ have been used to compute the numerical value of the partial derivatives.

It can be noted that $f_1(X_1^{(0)}, X_2^{(0)}$ is the calculated value of K_1 for the estimated values of $X_1^{(0)}$ and $X_2^{(0)}$

But this calculated value of K_1 is not the value specified by eq.(1.9) unless our estimated values $X_1^{(0)}$ and $X_2^{(0)}$ are correct. If $\triangle X_1^{(0)}$ is designated as the specified value of K_1 minus the calculated value of K_1 and define $\triangle K_2^{(0)}$ similarly

$$\begin{bmatrix} \triangle K_1^{(0)} \\ \triangle K_2^{(0)} \end{bmatrix} = J^{(0)} \begin{bmatrix} \triangle X_1^{(0)} \\ \triangle X_2^{(0)} \end{bmatrix} \quad \text{--------------} 1.16$$

So by finding the inverse of the jacobian it will be possible to determine $\triangle X1(0)$ and $\triangle X2(0)$. However, since the series expansion has been truncated, these values added to the initial guess do not determine the correct solution and so it is necessary to try again by assuming new estimates $X_1^{(1)}$ and $X_2^{(1)}$ where

$$X_1^{(1)} = X_1^{(0)} + \triangle X_1^{(0)}$$

$$X_2^{(1)} = X_2^{(0)} + \triangle X_2^{(0)}$$

And the process is repeated until the correction become so small that they satisfy a chosen precision index.

To apply the Newton – Raphson method to the solution of load – flow equations the bus voltage and line admittance may be expressed in polar form or rectangular form. If polar form is chosen and separate equation (1.7) into its real and imaginary components with

$V_K = |V_k| \angle\delta_k \quad V_n = |V_n| \angle\delta_k$ and $Y_{kn} = |Y_{kn}| \angle\theta_{kn}$

Will now become

$$P_K - jQ_k = \sum\nolimits^{N}_{n=1} |V_K V_n Y_{Kn}| \angle\theta_{Kn} + \delta_n - \delta_K \quad \text{---------} \quad 1.17$$

$$P_K = \sum\nolimits^{N}_{n=1} |V_K V_n Y_{Kn}| \cos(\theta_{Kn} + \delta_n - \delta_K) \quad \text{-------} \quad 1.18$$

$$\theta_K = -\sum\nolimits^{N}_{n=1} |V_K V_n Y_{Kn}| \operatorname{Sin}(Q_{Kn} + \delta_n - \delta_K) \quad \text{-------} \quad 1.19$$

As in the Gauss – Seidel method the swing bus is omitted from the iterative solution to determine voltages since both magnitude and angle of the voltage at the swing bus are specified. Specifying P and Q at all buses except the swing bus where, voltage magnitude and angle are specified.

The specified constant values of P and Q correspond to the K constants in equation (1.15). The estimated values for X_1 and X_2 in eq. (1.15) These estimated values are added to calculate values of P_K and Q_K from eqs. (1.18) and (1.19) and define

$$\Delta P_K = P_{K,\ spec} - P_{K,\ Calc}$$

$$\Delta Q_K = Q_{K\ spec} - Q_{K\ Calc}$$

Which corresponds to the Δ K values of eq. (1.16).

The jacobian consists of the partial derivatives of P and Q with respect to each of the variable in eq. (1.18) and (1.19). The column matrix element $\Delta \delta_K^{(0)}$ and $\Delta |V_K^{(0)}|$ correspond to $\Delta X_1^{(0)}$ and $\Delta X_2^{(0)}$ and are the correction to be added to the original estimates $\delta_K^{(0)}$ and $|V_{K1}|^{(0)}$ to obtain new values for computing $\Delta P_K^{(1)}$ and $\Delta Q_K^{(1)}$. For the sake of simplicity only the matrix equation of three buses will be written if the swing bus is number 1, then the calculation will start from bus 2 since voltage magnitude and angle are specified at the swing bus. In matrix form.

Equation (1.20)

$$\begin{pmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_2 \\ \Delta Q_3 \end{pmatrix} = \left(\begin{array}{cc|cc} \partial P_2 | \partial \delta_2 & \partial P_2 | \partial \delta_3 & \partial P_2 | \partial |V_2| & \partial P_2 | \partial |V_2| \\ \partial P_3 | \partial \delta_2 & \partial P_3 | \partial \delta_3 & \partial P_3 | \partial |V_2| & \partial P_3 | \partial |V_3| \\ \hline \partial Q_2 | \partial \delta_2 & \partial Q_2 | \partial \delta_3 & \partial Q_2 | \partial |V_2| & \partial Q_2 | \partial |V_3| \\ \partial Q_3 | \partial \delta_2 & \partial Q_3 | \partial \delta_3 & \partial Q_3 | \partial |V_2| & \partial Q_3 | \partial |V_3| \end{array}\right) \begin{pmatrix} \Delta \delta_2 \\ \Delta \partial \delta_3 \\ \Delta V_2 \\ \Delta V_3 \end{pmatrix}$$

The superscripts which would indicate the number of the iteration are omitted in eq.(1.20) because of course, they change with each iteration.

The elements of the jacobian are found by taking the partial derivatives of the expressions for P_K and Q_K and substituting therein the voltages assumed for the first iteration or calculated in the previous iteration. The jacobian has been partitioned to emphasize the different general types of partial derivatives appearing in each sub – matrix. For instance from eq. (1.18)

$$\partial P_K | \partial \delta_K = -| V_K V_n Y_{Kn} | \ \mathrm{Sin}\,(Q_{Kn} + \delta_n - \delta_K) \quad \text{-------} \quad (1.21)$$

where $n \neq K$

$$\partial P_K / \partial \delta_K = \sum_{\substack{n=1 \\ n \neq K}}^{N} | VKVn\ Ykn | \ \mathrm{Sin}\,(QKn + \delta_n - \delta_K)$$

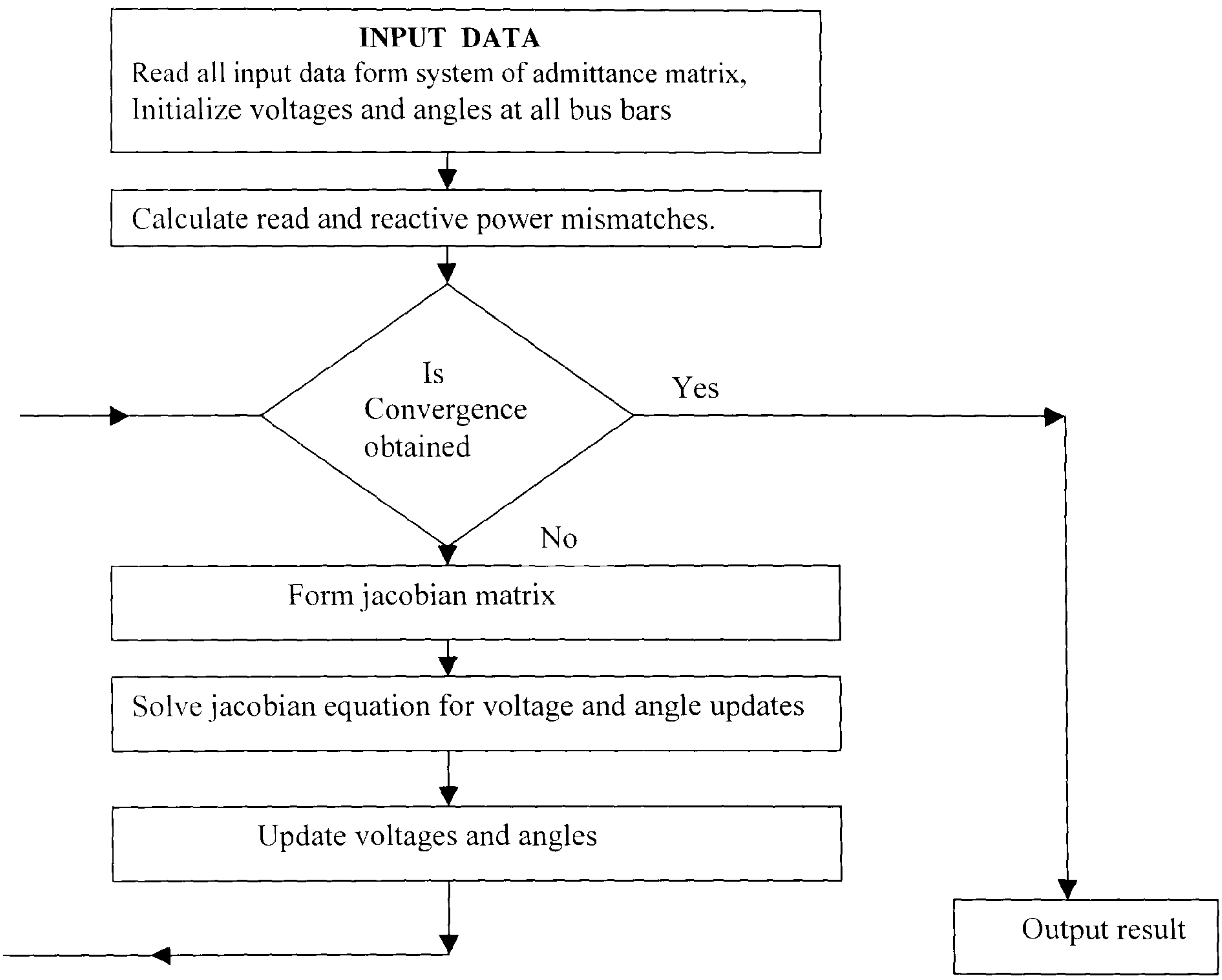
In the above summation $n \neq K$, which is apparent since δ_K drops of Eq. (1.17) when $n = K$ Similar general forms of partial derivatives may be found from Eq. (1.18) and (1.19) for calculating the elements in the other sub matrices.

Equation (1.20) and similar equations involving more buses are solved by inverting the jacobian.

The values found for $\triangle \delta_K$ and $\triangle |V_K|$ are added to the previous values of voltage magnitude and angle to obtain new values for $P_K^{(1)}$,Calc and $Q_K^{(1)}$,Calc for starting the next iteration. The process is repeated until the precision index applied to the quantities in either column matrix is satisfy. To achieve convergence, however, the initial estimates of voltage must be reasonable, but this is seldom a problem in power system work.

Voltage controlled buses are taken into account easily, since the voltage magnitude is constant at such a bus then unit in the jacobian the column of partial differentials with respect to voltage magnitude of the bus . Since at this point the value of Q needed at the bus the row of partial differentials Q is omitted for the voltage controlled bus. The value of Q at the bus can be determined after convergence by Eq. (1.19). The Newton – Raphson method, as noted previously may also be used when equation are expressed in rectangular form. The equation is determined in polar form because the jacobian provides interesting information which is lacking in the rectangular form. For instance the dependance of P_k and δ_K and of Q_K on $|V_K|$ is seen immediately in the jacobian in the polar form.

Flow diagram of the basic Newton – Raphson load – flow algorithm.



DEFINATION OF TERMS

TERMS	DEFINATION
A. G. C	Automatic Generation Control
S.C.A.D.A	Supervisory control and data acquisition
P_K	Real or active power
Q_K	Reactive or quadrature power
V_K	Voltage magnitude
ϑ_k	Voltage phase angle
E_S	Supply power
V_S	Supply voltage
ϑ_s	Supply voltage phase angle
P.U	Per unit

CHAPTER TWO

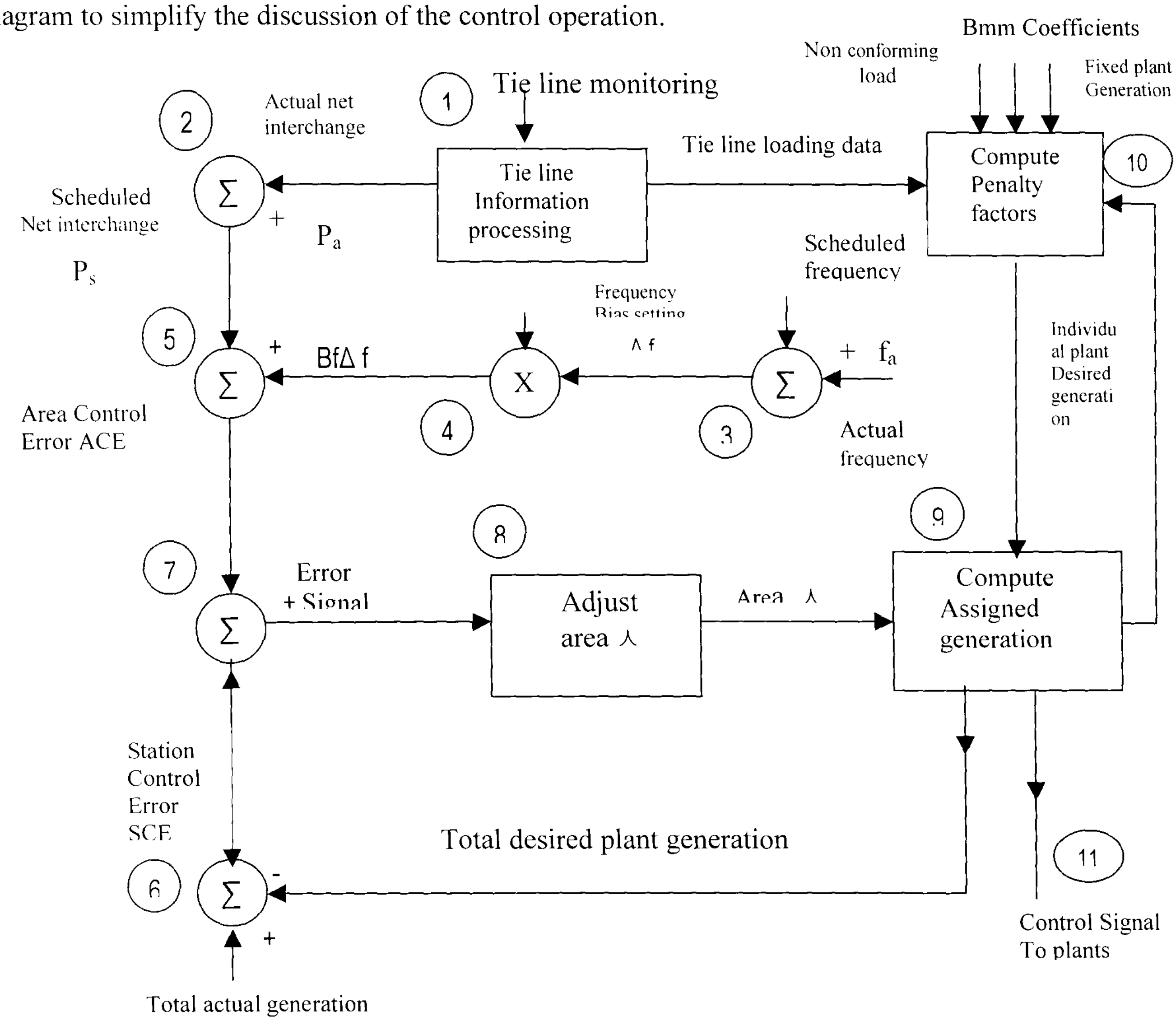
COMPUTER TASKS IN POWER SYSTEMS

2.1 AUTOMATIC GENERATION CONTROL

Computer control of the output of each plant unit within a plant is common practice in power ;ystem operation by continually monitoring all plant outputs and the power flowing in nterconnections interchange of power with other system is controlled. Most control system are ligital or combination of digital and analog. This is one of variety of ways in which computer :ontrol is accomplished.

ı discussing control the term area means that part of an interconnection system in which one or ıore companies control their generation to absorb all their own load changes and maintain a pre rranged net interchange of power with other areas for specified periods. Monitoring the flow of ower on the tie line between area determines whether particular area is absorbing satisfactorily all he load changes within its own boundaries. The function of the computer is to require the area to bsorb its own load changes to provide the agreed net interchange with neighboring areas, to letermine the desired generation of each plant in the area for economic dispatch, and to cause the ırea to do its share to maintain the desired frequency of the interconnection system.

The block diagram Fig (2.1) below indicates the flow of information in a computer controlling a particular area. The numbers enclosed by a circle adjacent to the diagram identify positions on the liagram to simplify the discussion of the control operation.



The larger circles on the diagram enclosing the symbols X or (Σ) indicates point of multiplication or algebraic summation of in coming signals.

At position 1 processing of information about power flow on tie lines to other control areas is indicated. The actual net interchange P_a is the algebraic sum of the power on the tie lines positive when net power is out of the area. The prearranged net interchange is called the scheduled net inter change P_s.

At position 2 the scheduled net interchange is subtracted from the actual net interchange.

The condition where both actual and scheduled net interchange are out of the system and therefore positive.

Position 3 on the diagram indicates the subtraction of the scheduled frequency f_s (for instance 6Hz) from the actual frequency f_a to obtain $\triangle f$, the frequency deviation. Position 4 on the diagram indicates that the frequency bias setting Bf, a factor with negative sign, is multiplied by $\triangle f$ to obtain a value of megawatts called the frequency bias $B_f \triangle f$.

The frequency bias which is positive when the actual frequency is less than the scheduled frequency is subtracted from $P_a - P_s$ at position 5 to obtain the area control error (ACE), which may be positive or negative.

$$ACE = P_a - P_s - Bf\,(f_a - f_s) \text{ ---------------- } (2.1)$$

A negative ACE means that the area is not generating enough power to send the desired amount out of the area. There is a deficiency in net power output. Without frequency bias the indicated deficiency would be less because there would be no positive offset B $\triangle f$ added to p_s (subtracted from P_a) when actual frequency is less than scheduled frequency and the ACE would be less. The area would produce sufficient generation to supply its own load and the prearranged nterchanged interchange but would not provide the additional output to assist neighboring inter connected areas to raise the frequency.

Station control error (SCE) is the amount of actual generation of all the area plants minus the desired generation as indicated at position 6 of the diagram.

This SCE is negative when desired generation is greater than existing generation.

The key to the whole control operation is the comparison of ACE and SCE. Their difference is n error signal, as indicated at position 7 of the diagram. If ACE and SCE are negative and equal, the deficiency in the output from the area equals the excess of the desired generation over the ctual generation and no error signal is produced. However, this excess of desired generation will ause signal indicated at position 11 to the plants to increase their generation to reduce the magnitude of the SCE, SCE and resulting increase in output from the area will reduce the magnitude of the ACE at the same time.

f ACE is more negative than SCE, there will be an error signal to increase the λ of the area and this increase will in turn cause the desired plant generation to increase (position 9). Each plant will receive a signal to increase its output as determined by the principles of Economic Dispatch.

This discussion has considered specifically only the case of scheduled net interchange out of the area (positive scheduled net interchange) greater than actual net interchange with ACE equal to or more negative than SCE.

Position 10 on the diagram indicates the computation of penalty factor for each plant.
Here the δ coefficients are store to calculate $\partial P_1 / \partial P_n$.

Non conforming loads, plants where generation is not to be allowed to vary and tie-line loading enter the calculation of penalty factors. The penalty factors are transmitted to the section (position 9) which calculates the individual plant generation to provide with economic dispatch the total desired plant generation.

One other point of importance (not indicated in Fig 2.1) is the offset in scheduled net inter change of power that varies in proportion to the inter-change integral in cycles between actual and ratio ($60H_2$) frequency. The offset is the direction to help in reducing the integrated difference to zero and thereby keep electric clocks accurate.

During normal operation, the following four tasks can be identified with the purpose of (A G C).

1) Matching of system generation and system load
2) Reducing the system frequency deviation to zero
3) Distributing the individual area generation among its generating sources so as to minimize operating cost.
4) Distributing the total system generation among the various control areas to comply with the scheduled tie flow.

The first is met by governor speed control. The other tasks require supplementary controls coming from the other control centres. The second and third tasks are associated with the regulation function or load frequency control and the last one with economic dispatch to AGC.

The above requirements are met with modest computer processing power of the order of 0.1 M IPS).

2.2 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)

The modern utility control system relies heavily on the operator control of remote plant. On this task, the operator relies on the SCADA for the following tasks.

1. Data acquisition
2. Information display
3. Supervisory control
4. Alarm processing
5. Information storage and reports
6. Sequence of events acquisition
7. Data calculations
8. Remote terminal processing.

Typical computer processing requirements of SCADA system are 1 – 2 MIPS.

2.3 GENERATION SCHEDULING

The operation scheduling problem is to determine which generating units should be committed and available for generation of the units. Units normal generation or dispatch are in some cases even the types of fuel to use.

In general, utilities may have several sources of power such as thermal plant (team and gas) hydro and pumped storage plants, dispersed generation (such as wind power or photo voltaire) inter connections with other national or international companies, etc. Also, may utilities use load management control to influence the loading factor, thus affecting the amount of generation required.

The economic effect of operations scheduling is very important when fuel is a major component of the cost. The time span for scheduling studies depends on a number of factors. Large steam turbines take several hours to start up and bring on-line. Moreover they have costs associated with up and down - time constraints and start ups. Other factors to be considered are maintenance schedules, nuclear refueling scheduling and long term fuel constraints which involve making decisions for one or more years a head.

Hydro scheduling also involves long term frames due to the large capacity of the reservoirs. However, many hydro and pump storage reservoirs have daily or weekly cycles.

Scheduling computer requirements will normally be within 2 MIPS.

2.4 NETWORK ANALYSIS

This is by far, the more demanding task, since it develops basic information for all the others and needs to be continuously up-dated. Typical computer requirements will be of the order of 5 MIPS.

The primary subject of power system analysis is the load flow or power-flow problem which forms the basis for so many modern power system aids such as state estimation, unit commitment, security assessment and optimal system operation. It is also needed to determine the state of the network prior to other basic studies like fault analysis and stability.

The methodology of load-flow calculations has been well established for many years and the primary advances today are in size and modelling detail. Simulation of networks with more than buses and 8000 branches is now common in power system analysis.

While the basic load-flow algarithan only deals with the solution of a system of continuously differentiable equations, there is probably not single routine program in use anywhere that does not model other features. Such features often have more influence on convergance than the programmes of the basic algarithan.

The most successful contribution to the load problem has been the application of Newton Raphson and derived algaritans. Those were finally established with the development of programming techniques for the efficient handling of large matrics and in particular the sporting oriented ordered estimation methods. The Newton algarithran was first enhanced by taking advantage of the decomposing characteristics of load-flow and finally by the use of reasonable approximation directed towards the use of constant Jacotism matrics.

CHAPTER THREE

3.1 DESIGN OF A NEW SYSTEM

The study of systems is by no means a new or even recent endeavour. Systems have been in use for thousands of years. The Egyptians employed a form of a book-keeping system over 5000 years ago for keeping their accounts, while phonenician astronomers studied systems of stars for the purpose of making predictions. Man has sought from beginning of time, to find relationships to generalize these relationships, and to explain what he can see, hear, touch, smell, and reason.

All man's history has been a continuing enlargement of this theme. Meaningful and durable relationships must be uncovered if we are to expand man's knowledge and successfully administer his affairs. The scientific method of investigation, which necessitate such meaningful and durable relationship for its results, is system analysis in the broadest sense.

Systems today are essential to the operation of any part of a business. They must be made to function at peak efficiency if a business is to survive. But a system can function only as effectively as users such as the accountant, business manager, and other responsible individuals within the company to make it function. To make a system function at maximum capacity demands more of its users than that they have a superficial knowledge of how to use the system.

3.2 SYSTEM DEVELOPMENT

A company may initiate a new system development project for a number of reasons:

a) Problem with the existing system:- Errors, delays, system inefficiencies and the desire to increase profits or reduce costs by eliminating these deficiencies, constitute a major impetus for system development.

b) The desire to exploit new opportunities: New markets, new production facilities, and new ways to achieve competitive advantage through the use of information systems are examples of new opportunities that often cause systems development to occur.

c) Increasing competition: For example, a competitor's new computerized system might provide faster and better customer service, forcing a company to keep pace in order to remain competitive.

d) The desire to make more effective use of information: Managers seek more information, so they can make better business decision.

e) Organizational growth: Companies experiencing growth require expanded and more powerful systems to meet the needs of increasing sales, book-keeping requirements and customer service.

f) A change in the market or external environment: The changing needs of customers, suppliers and governmental laws and regulations can result in major changes to existing computer systems.

3.3 FACTORS FOR SUCCESSFUL SYSTEM DEVELOPMENT

(1) Support at top – level managers
(2) Involvement of users at all stages
(3) Clearly defined system goals and objectives
(4) A focus on the most important problem or opportunities
(5) A simple and straight forward design
(6) Good training programs for all involved
(7) A well-defined and organized maintenance program

SYSTEM ANALYSIS AND DESIGN

Once the objectives of the system have been determined, the analyst can proceed with his investigation t o determine whether the existing system, be it manual, mechanical, punch-card or computerized, is adequate or whether this system should be modified, up-dated or replaced. Such analysis is termed a feasibility study.

FEASIBILITY STUDY

A complete and effective feasibility study would require an overall study of the entire organization. Before initiating such a study, the management of the organization should be apprised pf the fact that a sufficiently detailed, well-planned and executed feasibility study is both expensive and time consuming. Management should also be made aware that such a study can be beneficial to the organization regardless of study's outcome. For example, should the study reveal that the existing system is sufficient and appropriate for the organization's needs, and therefore should not be changed or replaced, substantial time and money can be saved for the organization in not needlessly attempting to develop a replacement system. Also, management could be assured that for their purposes, the existing system is the most efficient and competitive possibly.

The size and complexity of a feasibility study necessitates that it be broken down into several less comprehensive steps. Although these steps may differ in name, they will be similar in content to the following five steps:

1. Initialization
2. Selection of objectives
3. Detailed analysis
4. Resource allocations
5. Conclusion.

nitialization: In this phase of the study, contact should be made with employees associated with he existing system, from the lowest level employee through management personnel, in order to levelop a clear understanding of he advantages and disadvantages of the existing system as well ıs to point out any unsolved problems. For future analysis, a study team should be formed ;onsisting of at least one member from each of these areas. The first task of this team will be to letermine the present and future requirements of the system, the extent of available equipment and nethods relating to this system and what expenditures of personnel, time and money can be ınticipated to complete the feasibility study.

Selection of objectives: In this phase of the study, the system specifications and objectives should)e written down in detail accompanied by a realistic timetable for the completion of the feasibility tudy. Krauss suggests that the answers to the questions below will help the analyst determine this nformation.

Management:

1. What are the past and future objectives?
2. What is the general attitude?
3. What is the underlying philosophy?
4. What organizational changes are planned?
5. What are the unfulfilled information needs?
6. How receptive is management to new techniques or change?

Procedures:

1. What work is performed?
2. In what sequence does the work take place?
3. Who perform the functions?
4. How many people are needed?
5. When is the function performed?
6. What equipment is used?
7. Is the function needed?
8. What inputs and outputs are involved?
9. How much volume is there – average, peak, growth?
10. How much time is required for the function?
11. How often is the work done?
12. What controls are required?
13. What are the turn around time requirement?
14. What "business rules" apply to each function?

Cost:

1. How much does the present system cost?
2. How much is spent on forms and supplies?
3. What are the costs for carrying inventory or receivables awaiting collections?
4. What are the personnel cost?
5. What overhead is charged?

Effectiveness:

1. Does the current system do what was intended?
2. What are the strong points?
3. What are the disadvantages?
4. What effects would expansion have?
5. Is the current output useful?
6. How much inefficiency and duplication of effort exists?
7. What inter-department relationship exist?

There are several ways to go about obtaining the answers to these and other questions. Three of the most common fact gathering techniques which are currently used to obtain information about the present system and future needs are:

1. Interviewing
2. Reviewing historical records
3. Sampling and estimating

Interviewing is probably the most productive of the three and usually begins with top management to obtain broad background information; then with middle or first-line management, who provide the details and finally, the individual workers are questioned.

One must bear in mind that the lowest graded worker can often point out the imperfections in the existing system and occasionally will even suggest worthwhile remedies.

The degree to which historical records can be beneficial is greatly dependent upon the nature and rate of growth of the business. All too often, the analyst will discover the records are often too poorly kept or too out of date to serve as predictors with any degree of certainty. In these cases, the records are better put aside and their absence compensated for by a more in-depth analysis of other source data.

It is often helpful to gather sample data from which estimates or projections can be made which serve to either confirm or cast doubt on conclusions reached by other means. This technique however should be used cautiously, as substantial errors are possible if one is not experienced and knowledgeable concerning its use.

Detailed Analysis
In this phase, the present and past systems used by the company are examined in comparison to other companies that have instituted such studies. Careful consideration should be given to the relationship between the dollar cost of the system study and tangible savings and benefits, not only with regard to profits, but with respect to saving in space, time, experience gained, increased competitive potentials, and so on.

The relationship between the system under investigation and other independent and inter-dependent systems within the company should be determined. In determining this relationship, each of the systems should be analyzed and compared with the remaining systems concerning their functional design as opposed to their organizational arrangements.

Resource Allocations
An account should be taken of all the company's resources, including such items as manpower, money, time, space, etc. For example, a hypothetical list of proposed system cost and benefits is given in figure below. Included should be a detailed statement t concerning whether or not each of these resources is being efficiently utilized.

PROPOSED SYSTEM COSTS:

Hardware

Basic processor
Storage and input output
Communications
Facilities
Equipment maintenance

Operating expenses

Programmers to maintain the system
Equipment operators
Keypunch and media prepares
Data collectors
Data control and correction
Electricity, heating and air conditioning
Cards, paper and tapes

Developmental Costs

Hiring and training programmers and analysts
Salaries of programmers and analysts
Salaries of additional study team or developmental personnel
Disruption of normal operations
Retraining of displaced personnel
Establishment of new files

Proposed system benefits

Decreased operating costs
Fewer people
Less inventory
Fewer penalties for late delivery or payment
Reduced spoilage of goods
Lower transportation or purchasing costs for material
Fewer shortages to interrupt production
Better scheduling of production

Increase Revenue

Ability to handle more customers with existing facilities
More customers by faster or more dependable service
Higher price or more customers from better equality of product

CONCLUSIONS:

A written report incorporating the study team's findings and recommendations should be submitted to management. These recommendations should be supported in detail, making certain to high light any anticipated benefits in addition to pointing out the degree of uncertainty and risk inherent in the recommendations.

Such feasibility study could have only two possible outcomes. The first possible outcome is that the present system is superior to any other system thus far proposed or evaluated. In this case, the study would be discontinued for the immediate feasible future. At such time as new developments should arise, the feasibility study could be reinitiated.

The second possible outcome could be that the present system is not the most effective and efficient system for the company's needs. In such a case, two possible alternatives could be suggested as a result of the feasibility study: modify the existing system or develop a new system.

3.4 MODIFY THE EXISTING SYSTEM

Inexpensive modifications to the existing system are often sufficient for user's needs. A simple modification such as the standardizing of invoice layouts that had previously varied from one department to another within the company would for example, lower the cost of the forms, simplify personnel training and reduce possible errors in using and understanding these forms. Modification of the existing system could also include the replacing of manual methods with mechanical or computerized methods, or the replacement of existing equipment with more sophisticated and more efficient equipment.

3.5 DEVELOPING A SYSTEM DESIGN

The developing of a system can be reduced to three fundamental stages: the investigation stage, the hypothesis stage and the implementation stage.
Investigation: The first phase of any system investigation is to acquire a detailed understanding of the existing system. A great deal of this information should have been revealed in feasibility study, but it will be restated for emphasis.

The investigation stage is a period of intensive data collection and interviewing. A substantial amount of written material is collected in this process and generally takes one or more of the following forms.

1. Representative input and output data
2. Practical examples of the existing system's malfunctions (if any)
3. Reports and commentaries indicating previous studies of, or attention given to the same or similar problems.

Equally, as important as written materials is the interview. Many items can be determined from an interview that would be almost impossible to obtain from written documents. However, one must approach the interview with caution since interviews can easily become confused, redundant and time-consuming. The interviewer must make every effort to eliminate any bias that might be injected as a result of the position and personality of the person being interviewed. He must also be careful to avoid the common pitfalls that can occur in interviewing. Some of these common errors are:

1. Interrupting the story to insert your own ideas and views
2. Allowing the direction of the interviewed to be diverted onto non-production paths
3. Allowing blanket statements and broad generalizations to obscure the facts
4. Leaving the interview only half understanding an issue or problem
5. Allowing oneself to be overpowered by the person being interviewed instead of the interviewer.
6. Allowing oneself to become involved in operational problems, thus distracting your attention from the prime purpose of information gathering.
7. Asking leading questions which can be answered with a ''yes'' or ''no'' as very often this kind of questions calls for an opinion and not fact.

3.6 STEPS IN A SYSTEM DESIGN

ANALYSIS OF PRESENT SYSTEM

↓

DEVELOP A CONCEPTIONAL MODEL

↓

TEST THE MODEL

↓

PROPOSE A NEW SYSTEM

↓

PILOT INSTALLATION OF THE NEW SYSTEM

↓

FULL INSTALLATION OF THE NEW SYSTEM

After all interviews have been completed and their results have been assembled, the conceptual mode will begin to take shape. The conceptual model is the analysts first idea concerning how to attack the problem concerning the manner in which the system should be redesigned. The analyst should be careful not to attempt to draw conclusions or to attempt to solve the problem during this stage, to make a concerted effort to simply collect data.

Hypothesis: Upon completion of the analysis of the existing system and the development of a conceptual model (investigation stage), the analyst must test the conceptual model and propose a new system (hypothesis stage).

The conceptual model to be tested can appear in many forms. If it were to appear in a mathematical form, for example, its analysis would be reasonably routine, however, the problem does not usually appear this way. Therefore, there remains only one effective means to evaluate the model. This means is simply to expose the model to its potential users for their analysis and comment. This should be done as early as possible after the completion of the investigation stage. The problem becomes even more difficult in the case of a new system, where the potential users have had little o no previous exposure to this or a previous, but similar system.

In such cases, it is desirable to test sub-systems of the overall system separately as well as testing the overall operation of the system in any way feasible. It is important to verify that the sub-systems are compatible and can function together to produce the desired results. The unstructured or non-mathematical nature of most business systems must be given careful consideration in designing the testing format to be utilized. This should be considered in much the same way as it will be in the design of the system itself.

Implementation: If possible, a pilot implementation study should be performed, as this type of study has the distinct advantage of allowing the system in miniature to operate under battle condition. This means that any defect can be corrected or any changes made prior to the making of any large-scale commitments.

In this analysis of this pilot study, the analyst must realize that it is difficult, if not impossible to design a completely optimum system. Even if one were able to develop such a system, changes in input and output requirements might necessitate that the analyst settle with a system design which is somewhat less than optimum. The system designer must realize that this role is simply to improve the existing process to the greatest extent practically possible in the shortest possible time. Otherwise, a great deal of time can be endlessly expanded by the analyst in an attempt to produce the optimum system, not realizing that in so doing, the completion date of the system is being postponed and the company is losing the benefit of the use of the new system.

Once the pilot study has been made to perform satisfactorily, it can be expanded, step by step, until it covers the full operational scope for which the system was designed.

3.7 SYSTEM FLOW CHART

A flow chart is a means of visually presenting the flow of data through an information-processing system, the operations performed in the system and the sequence in which these operations are performed. As program flow chart is useful in understanding a computer program, the system flow chart is even more useful in understanding a computerized system.

A system flow chart pictorially describes the flow of data through all the parts of a system.

CHAPTER FOUR

IMPLEMENTATION OF DESIGN

4.1 SYSTEM IMPLEMENTATION

SYSTEM TESTING: A system must be thoroughly tested before it is placed into actual operation. The testing process involves analysts, programmers, management and individual user departments and generally consist of three phases.

In the first phase, the lead programmer on the project must test each of the program segments separately and in combinations. Program test data and verified output should be included in the final program documentation. When all program testing and documentation has been completed, the lead programmer then forwards a complete set of fully tested and documented programs to the project analyst.

In the second phase of system test, the analyst checks program flow charts and decision tables against original specifications. He will subject the programm to actual data as well as data with planted errors to verify that they will be detected should it arise in actual use. When he has thoroughly examined and reviewed the logic of each sub-system, the flow of information through the system, and the overall system, he will gather together systems test data or actual data and create special test files.

In the third and final phase, the entire system is tested utilizing actual machines and employees. The system is tested down to the most minute detail. Forms are checked, schedules are checked, operating instructions are verified, and the movement of data and results are tested. In cases where there is no existing automated system to test against individuals departments may ask or be asked to check the accuracy of the system's output manually. If a company auditor is available, he should be consulted from time to time throughout this process, as the system may be audited by non-company data-processing auditors at a future date.

The system is now ready to be put into actual use. This, of course, require that all files be first created and then tested before the change over takes place. Once the system has been implemented, it must be constantly tested and improved if it is to remain efficient and effective. A system can be thought of as a living thing requiring that it be constantly nurtured and cared for if it is to survive and grow. In other word, the essence of program testing also referred to as program validation is to determine whether any error still remain in the program. The testing is the process of running the computer program and evaluating the program results in order to determine if any errors exist. The testing is done by running the program with various sets of input values so as to be sure that the expected result is gotten.

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Once the pilot study has been made to perform satisfactorily, it can be expanded, step by step, until it covers the full operational scope for which the system was designed.

In other word, implementation can be said to be once a program has been tested and found working as required, the next stage is the implementation of the program. The implementation stage is concern with making the program fully operational. That is, it involves applying the programs to solve the problem it is meant to solve.

SYSTEM DOCUMENTATION: A system cannot be completely effective unless it is adequately documented. It should be documented as it is being created. That is, at various stages or intervals in the system development, status reports should be prepared for those management personnel for whom the system is being designed. Such reports would include flow charts, decision table, output or report forms and other documents thus far developed. Also included would be any problems encountered, suggested solutions, and resulting schedule revisions. In this way, management is kept abreast of the system's progress so that where necessary, they can offer criticisms or suggest change while it is still economically and physically possible to make these changes without it being necessary to revise the entire system.

These progress reports provide an excellent basis on which to build additional documentation. Instructions and narrative descriptions must be prepared for every phase and part of the system, including system logic, timings, user instructions, instructions for operations personnel in the data-processing center, and instruction concerning the transmission of data and results. Much of this can be incorporated into a procedures manual. This manual stipulates the relationship between personnel in the application areas affected by the system and the data-processing center. It should relate, in detail, exactly what procedures must be employed by the user to operate the system efficiently and effectively.

In other word, system documentation is the description of the program in the proper form for users and to enhance maintainability. It describes the workings of a program and how expected problems could be solved. Documenting a program is very important because it aids the users in understanding the program better and it also aids maintenance of such program. The documentation may be internal – in the form of comments which exist within the program or may be external in the form of a written description and structured diagrams.

4.2 ACQUISITION AND PROGRAMMING

A program is defined as an instruction set describing the logical steps the computer will follow to solve a particular problem. The art of program writing is programming and it involves the following steps:

1. problem definition
2. Problem analysis
3. Algorithan development
4. Flow charting
5. Coding the program
6. Prepare test data, run and debug the program
7. Program documentation

PROBLEM DEFINITION: Before a program can be written to perform a particular task, the nature and complexity of the problem or task must be known. Naturally, mathematical problems are easier to define since formulas are involved and hence well defined.

Some problems however, may be very complex. A commercial data processing may involve so many sub-tasks, procedures and routines that must be well defined and formulated using mathematical statements and operators. When problems are well defined then the solution to the problems can be professed.

PROBLEM ANALYSIS: Problem analysis involves analysing the various procedures or routine defined to find a method of solution. With mathematical problems the data are either individual items or array of data.

The analysis involved in a commercial data processing may involve manipulating the records in a file, establishing a relationship between the various data elements and the description of the medium of storage be it tape or disk.

The nature of the problem and analysis guide on how data can be represented within the computer for easier manipulation.

ALGORITHMS: An algorithm is a step by step method or rules for solving a problem in a finite sequence of steps. Having defined and analysed a problem the next stage is to formulate an algorithm which is a problem solving procedure to perform the task at hand. Algorithm is mostly used and accepted term in the field of mathematics and computing science. It involve describing in literal terms the steps to be taken to solve a given problem.

FLOW CHARTING: Flow charting is one of the widely used techniques for specifying an algorithm in computer science. A flow chart can simply be defined as diagrammatic representation of algorithms. It is pictorial representation of a complex procedure with considerable clearity.
Flow charts have the capabilities of:

a) Visually starting the resources and considerations that are needed to design a system.

b) Illustrating the logical sequence in which thins happen

c) Graphically showing the decision alternatives.

CODING THE PROGRAM: Once the steps of the solution has been ordered and outlined, the next stage is the transformation of these steps to the form understandable by the computer. Therefore, the coding stage covers the transformation of the design made earlier into a chosen computer language as well as entering the programs into the computer. The computer language to be used may be machine language which is directly understandable by the computer or assembly language or high level language which would require a translator. High level language (Fortran) is used for this project. Programming, in other words, to select and acquire hardware/software or to write the needed software can be referred to as Acquisition and Programming.

4.3 TRAINING AND CONVERSION OF MANPOWER

CHANGE OVER

The change over from the old to the new system may take place when: the system has been proved to the satisfaction of the system analyst and the other implementation activities have been completed. User managers are satisfied with the results of the system tests, staff training and reference manuals.

The target date for change over is due. The changeover may be achieved in a number of ways. The most common methods are direct, parallel running, pilot running and staged change over:

a) **DIRECTOR CHANGE OVER**: This method is the complete replacement of the old system by the new, in one move. It is a bold move, which should be undertaken only when everyone concern has confidence in the new system. When a direct changeover is planned, system tests and training should be comprehensive, and the changeover itself planned in detail. This method is potentially the least expensive but the most risky.

For security reasons, the old system may be held in abeyance, including people and equipment. In the event of a major failure of the new system the organization would revert to the old system.

b) PARALLEL RUNNING: This means processing current data both old and new system to cross-check the results.

Its main attraction is that the old system is kept alive and operational until the new system has been proved for at least one system cycle. Using full live data in the real operational environment of place, people, equipment and time. It allows the results of the new system to be compared with the old system before acceptance by the user, thereby promoting user confidence.

Its main disadvantage is the extra cost, the difficulty a (sometimes) the impracticability, of user staff having to carry out the different clerical operations for two systems (old and new) in the time available for one.

c) PILOT RUNNING: This is similar in concept to parallel running. Data from one or more previous periods for the whole or part of the system is run on the new system after results have been obtained from the old system, and the new results are compared with the old. It is not as disruptive as parallel operation, since timing is less critical. This method is more like an extended system, test, but it may be considered a more practical form of changeover for organizational reasons.

d) STAGED CHANGE OVER: This involves a series of limited size direct change over, the new system being introduced piece-by-piece. A complete part, or topical section, is committed to the new system while the remaining reports or sections are processed by the old system. Only when the selected part is operating satisfactorily is the remainder transferred. This method reduces the risks inherent in a direct changeover of the whole system and enables the analyst and users to learn from mistakes made as the changeover progresses.

Disadvantages:

a) It creates problems of controlling the selected parts of the old and new system

b) It tends to prolong the implementation period.

CONTROL:

Which ever method is adopted for the changeover from an old to a new method, a high priority must be given to establishing controls, by value or quantity, in order to maintain the quantitative integrity of the system. Users should keep overall control records incorporating both computer and clerical control figures to prove that the changeover has not corrupted this integrity.

This aspect of control at changeover cannot be over-emphasised since not all existing systems or their control methods are in a good state of order.

HAND OVER:

Once the system has been working for an agreed period of time, the systems analyst will wish to withdraw. Prolonged involvement of the systems analyst with a working system should be avoided. The system become the responsibility of a maintenance group within the computer department instead of the development staff. This hand-over point should be established as part of the implementation plan.

The users must be satisfied that the system works properly and meets all their requirements by the time hand-over take place. It is essential, therefore, that the hand-over takes place formally, with a clear understanding on all sides that the systems analyst's involvement has come to an end.

4.4 TRAINING OF PERSONNEL

Computer being complex and delicate, those involve in handling it need to be trained for effective handling of the system. The analyst need to make sure the personnel are up to date about the system to avoid unnecessary break-down of the system. One of the major criteria before hand-over is staff training.

4.5 MAINTENANCE

This includes whatever changes and enhancements needed to be made after the system is up and running.

CHAPTER FIVE

5.0 WHAT HAS BEEN ACHIEVED

INFORMATION OBTAINED IN A LOAD-FLOW STUDY:

The information which is obtained from digital solutions of load flow is an indication of the great contribution digital computers have made to the power system engineers ability to obtain operating information about systems not yet built and to analyze the effects of changes on existing systems. The following is not meant to list all information obtainable but to provide some insight into the great importance of digital computers in power-system engineering.

The print out results provided by the computer consists of a number of tabulations. Usually the most important information to be considered first is the table which lists each bus number and name bus- voltage magnitude in per unit and phase angle, generation and load at each bus in Megawatts and megavars line changing and megavars of static capacitors or reactors on the bus. Accompanying the bus information is the flow of megawatts and megavars from that bus over each transmission line connect to the bus. The totals of system generation and loads are listed in megawatts and megavars. The tabulation described is shown in
Appendix B attached for the system of five buses.

In the operation of power system any appreciable drop in voltage on the primary of the transformer caused by a change of load may make it desirable to change the tap setting on transformers provided with adjustable taps in order to maintain proper voltage at the load. Where a tap-changing has been specified to keep the voltage at a bus within designated tolerance limits, the voltage is examined before convergence is completed. If the voltage is not within the limits specified the program causes the computer to perform a new set of interactions with a one-step change in the appropriate tap setting. The process is repeated as many times as necessary to cause the solution to conform to the desired condition. The tap setting is tested in the tabulated results.

A system may be divided into areas or one study may include the systems of several companies each designated as a different area. The computer program will examine the flow between areas and deviations from the prescribed flow will be overcome by causing the appropriate change in generation of a selected generator in each area. In actual system operation of interchange of power between areas is monitored to determine whether a given area is producing that amount of power which will result in the desire interchange.

5.1 LIMITATIONS

In Gauss-seidel method of load flow solution convergence upon an erroneous solution may occur if the original voltages are widely different from the correct values. Experience with the Gauss-seidel method of power-flow problems has shown that an excessive number of interactions are required, the voltage corrections are within an acceptable precision index if the corrected voltage at a bus merely replaces the best previous value as the computation proceed from bus to bus.

Using New-Raphson method of power flow problems, computing the elements of the Jacobian is time-consuming, and the time per iteration is considerably longer for Newton-Raphson method.

5.2 RECOMMENDATION

The appearance of large digital computer paved way for unprecedented developments in power system analysis and with them the availability of a more reliable and economic supply of electrical energy with tighter control of the system frequency and voltage levels. Hence I will thereby recommend that computer should be given more emphasis in Shirro Power station and Nigeria electrical development in the area of system protection, automatic generation control and other areas, to make the system more effective and efficient.

5.3 CONCLUSION

The computer industry began in the late forties with a very small initial investment, and has been increasing both in strength and importance. When one looks back with analytical mind, we can conclude that computer technology keeps on advancing with remarkable increase in speed accuracy and reliability. Computing in whatever field, science, engineering, business and industry is reaching directly or indirectly into various aspects of our society thereby, without loss of generality has shrunk the world into such a compactness that no part can afford to lag behind or live in isolation. Computer has come to stay, hence efforts should be directed towards introducing computer into every facet of human endeavour.

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APPENDIX 'A'

One-line diagram:

(1) Birch ↑ ↑ Elon (2)

(5) Pine Maple (3)
↓ ↓

(4) Oak
↓

Data Supplied to the Computer

Table 1:

o	Length km	mi	R	X	R	X	Charging
					Per unit	Per unit	Mvar
	64.4	40	8	32	0.042	0.168	4.1
	48.3	30	6	24	0.031	0.126	3.1
	48.3	30	6	24	0.031	0.126	3.1
	128.7	80	16	64	0.084	0.336	8.2
	80.5	50	10	40	0.053	0.210	5.1
	96.5	60	12	48	0.063	0.252	6.1

At 138 KV

e 2:

	Generation P.MW Q Mvar		Load P, MW Q Mvar		V, per unit	Remarks
	…………..		65	30	1.04/0°	String bus
	0	0	115	60	1.00/0°	Load bus (inductive)
	180	….	70	40	1.02/0°	Voltage magnitude (constant)
	0	0	70	30	1.00/0°	Load bus (inductive)
	0	0	85	40	1.00/0°	Load bus (inductive)

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SHIRORO HYDRO POWER STATION LOAD FLOW STUDY

DATE 04/5/99 — TIME 00.00.12

3 ITERATIONS. SWING BUS IS 1.

REPORT OF POWER FLOW CALCULATIONS FOR AREA 1.

BUS	NAME	VOLTS	ANGLE	GENERATION MW	GENERATION MVAR	LOAD MW	LOAD MVAR	CAP/REAC MVAR	TO BUS	NAME	LINE FLOW MW	LINE FLOW MVAR	TAP
1	BIRCH	1.040	0.0	234.7	100.1	65.0	30.0		2	ELM	73.98	31.55	
									5	PINE	95.68	36.56	
2	ELM	0.961	-6.3	0.0	0.0	115.0	60.0		1	BIRCH	-71.81	-25.39	
									3	MAPLE	-43.59	-34.60	
3	MAPLE	1.020	-3.7	180.0	110.3	70.0	40.0		2	ELM	46.59	35.65	
									4	OAK	40.46	16.06	
									5	PINE	24.95	16.58	
4	OAK	0.920	-10.9	0.0	0.0	70.0	30.0		3	MAPLE	-38.74	-18.90	
									5	PINE	-31.25	-11.09	
5	PINE	0.96[illegible]	-6.2	0.0	0.0	85.0	40.0		1	BIRCH	-92.59	-29.18	
									3	MAPLE	-24.44	-19.62	
									4	OAK	32.03	6.77	
	AREA TOTALS			414.7	210.4	405.0	200.0	0.0					

SOLUTION TIME 0.10 SECONDS.
TOTAL TIME 0.54 SECONDS.

Digital computer solution of load flow study for the system of Appendix B
Base is 100MVA.