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MFTF-B LOAD-FLOW ANALYSIS: A MAINFRAME APPLICATION IMPLEMENTED ON A PERSONAL COMPUTER

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Lawrence Livermore National Laboratory

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MFTF-B LOAD-FLOW ANALYSIS: A MAINFRAME APPLICATION IMPLEMENTED ON A PERSONAL COMPUTER

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ABSTRACT

We have successfully implemented load-flow analysis on the IBM PC-XT/370. This involved obtaining a large program written specifically for the IBM/370 mainframe and adapting it for use on the PC-XT/370. Our procedure was straightforward, and the results we have obtained have been excellent.

The procedure described here is useful for updating a large number of mainframe IBM System/370 programs to run on the PC-XT/370, and yields a very powerful computational tool at a very attractive price.

THE PROBLEM

WHAT IS LOAD FLOW ANALYSIS?

Several computational methods have been developed to help engineers analyze the response of an ac electrical power system to various load patterns and generation schedules. Load flow analysis is a modeling methodology for a specific class of power-system problems involving the determination of the steady-state, complex values of 60-Hz conditions in a power system.

Some of the terminology of power-system engineering differs from that used in the electronics world. The following terms are used in this report:

Bus	A node of the power system. Usually, but not always, this is a physical busbar in a substation.
Line	A connection with a known impedance between buses. The term can denote an overhead transmission line, a cable, a transformer, or other types of apparatus.
Swing bus	The one bus in the network whose voltage is set a priori. All other bus voltages are determined with respect to the swing bus.
Apparent power	$S = VI^*$ (complex voltage times the conjugate of complex current). The apparent power is measured in V•A., kV•A, or MV•A. When a single number is given for KV•A, etc., it refers to the magnitude.
Power	$P = Re(S)$ measured in watts.
Reactive power	$Q = Im(S)$ measured in V•AR (volt-amperes reactive).
Voltage	Voltages are complex rms quantities, expressed in per-unit (pu) values (see Appendix A) to avoid unnecessary complexity in handling transformers.

For load-flow analysis, a power system is assumed to be balanced, i.e., all three phases are identical, and consequently, only one phase is considered. The system is modeled as a network of buses (nodes) interconnected by lines. Each line has a complex impedance. Each bus has a known generation (power input to the network) and load (power output from the network). One bus is designated as the swing bus and assigned a voltage value for purposes of the study. The analysis yields the complex voltages (expressed as magnitude and phase angle) at each bus, and the complex power flows and losses in each line.

A major source of complexity in load-flow analysis is that bus loads are held constant as the bus voltage varies. This assumption is correct for many typical power-system loads. Examples are regulated power supplies that maintain a constant output power, and motors whose speed is determined by the system frequency and whose speed varies only slightly with voltage. For the regulated power-supply loads in the MFTF-B Neutral Beam Power Supply System (NBPSS), the constant-load assumption is very good, but leads to a situation in which the load current increases as the bus voltage drops, making the problem nonlinear and requiring very complicated computation for even a two-bus problem. Fortunately, there is plenty of good, commercial software available to attack this problem.

Various numerical algorithms have been used for the load-flow problem; however, the Newton-Raphson method seems to be the most popular one. It is well suited to this type of problem because the approximate starting point of the solution is well known; that is, all of the node voltages are close to 1.0 pu (100%). See Ref. 1 for more details about power-system analysis generally and load-flow analysis in particular.

THE PERSONAL-COMPUTER SOLUTION

THE PC-XT/370

The Laboratory has no load-flow software on its mainframe computers. Over the years the IBM System/360/370 has been the most commonly used hardware for such applications because of its popularity with electric utility companies. A number of load-flow codes have been written for the IBM 360/370 computer system and are available at little or no cost to LLNL.

Last year IBM announced the PC-XT/370 microcomputer.[2] The machine can be purchased directly in this configuration, or one can be converted by adding three IBM-supplied boards to any IBM PC-XT. The PC-XT/370 will run most software that runs on the IBM System/370, subject to certain constraints. What this means is that just about any IBM System/370 software can now be run on a personal computer. This will enable users to run software on a machine that is fully under their control in the user-friendly, highly interactive environment associated with the personal computer. For some software applications, the PC-XT/370 may also provide an alternative machine to the CDC 7600, which is no longer available for Magnetic Fusion Energy Computer Center users.

Since the MFTF-B Power Supply Systems Group was planning to provide a number of PC-XT's for the engineers' use, we ordered one PC-XT/370 for testing and evaluation, and obtained a copy of the load flow package PSAP4000 from the Philadelphia Electric Company.

WHAT IS THE VM/CMS OPERATING SYSTEM?

VM/CMS is an acronym for IBM's Virtual Machine/Conversational Monitor System, the time-sharing system for the System/370 hardware. It includes facilities for using software designed to run under the various IBM batch environments; it is therefore possible to run almost any software developed for any IBM mainframe system in the VM/CMS environment. VM/PC is the operating system for the PC-XT/370 that emulates VM/CMS. It provides all the VM/CMS features relevant to the single-user environment of the PC-XT/370 except the Help facility, which is too big for the PC-XT/370. Most software that runs under VM/CMS will run without modification under VM/PC.

HOW DO YOU OBTAIN SOFTWARE?

There are a number of ways to locate suitable software for this environment. One particularly good catalog is the NASA <u>COSMIC Software Catalogue</u>.[3] This catalogue briefly describes each program and what type of computer the program was written for. There are over a thousand programs in this catalogue alone and most of them are very reasonably priced or are already owned by the Government.

If the software supplier has an XT/370 and a System/370 mainframe, the most convenient way to obtain software is for the supplier to write the program to floppy disks. If the supplier does not have an XT/370, then the program can be written to a magnetic tape. If the program is relatively short, it could possibly be transferred over the telephone using a 1200-baud modem and a file-transfer program such as KERMIT.

Because PSAP4000 is extremely large (there are over 43,000 lines of Fortran in the base package, plus numerous assembly-language routines that are linked with it), we elected to obtain the package by way of magnetic tape. Since we have a contract with UC Berkeley for the use of their System/370 system, we loaded the package on their machine. After we had it running, we took the PC-XT/370 to Berkeley and connected it through the high-speed coaxial link to the mainframe and copied the files onto it. For large files, this is the most desirable procedure; however, we have subsequently successfully transferred both text and executable System/370 files to the PC-XT/370 over the telephone using the KERMIT protocol.

LLNL has a site license with IBM for their VS FORTRAN compiler, which compiles both FORTRAN 66 and FORTRAN 77 and provides 3 different levels of optimization. We have had no difficulty compiling FORTRAN codes on the local PC-XT/370. A copy of this compiler is available from the author on floppy disks. There is an alternative to local compilation; the application can be compiled on the UC Berkeley machine, and the executable module can be downloaded onto the PC-XT/370.

OUR EXPERIENCE

THE PROBLEM WE FACED

We were looking for a convenient method to run load-flow studies for the NBPSS project. In the past we have done our studies on the General Electric Mark III time-share system with good results. However, this method is both expensive and inconvenient. We evaluated several of the recently marketed load-flow codes for the IBM PC and found that they were very expensive ($6000 and up) and that all of them had significant shortcomings for our application.

When the low-cost PC-XT/370 was announced, we decided to evaluate its usefulness for load-flow analysis. After evaluating a number of load-flow codes, we selected PSAP4000, which is maintained by the Philadelphia Electric Company and is capable of handling a 4000-node interconnected power system. This very flexible program can handle just about any possible configuration, and provides a variety of output options.

We succeeded in compiling the FORTRAN portion of the program at LLNL, but we needed the help of the UC Berkeley consulting staff to assemble the auxiliary codes and successfully link them with the main program. The assembly-language routines required either deletion of the system-specific portions or modification to work with a "generic" VM/CMS system. Once these changes were made, we were able to get PSAP4000 running on the UC Berkeley machine. After downloading the assembled modules and the FORTRAN source, we recompiled the latter and linked it with the assembled modules, ending up with a package that runs correctly on the local PC-XT/370.

WHAT DOES IT TAKE TO GET STARTED?

For most users, the most probable starting point will involve upgrading an IBM PC-XT to a PC-XT/370 by adding the three circuit boards provided by IBM. This enhancement costs less than $3000. In addition, we have found that a modem and an account at UC Berkeley are essential. The 10-Mb hard disk furnished with the PC-XT and the PC-XT/370 is not adequate to run nontrivial System/370 applications. We worked around this problem by installing a Univation 5-Mb removable-media hard disk drive and a half-height floppy drive in addition to the original 10-Mb fixed-disk drive. One could also install a higher-capacity fixed disk drive and have a system that is somewhat more convenient but less flexible. In any case, we can easily compile PSAP4000, run it, and store a reasonable amount of data in the space available with our present setup. If you are starting from scratch, we would suggest purchasing a PC-XT/370 with two half-height floppies and one of the new larger hard disks - say 30-40 Mb. This configuration would provide enough storage capacity for just about any System/370 software you might run and also would permit you to keep all of the required support software you will need. This might include a FORTRAN compiler, BASIC compiler, PC-DOS, VM/PC, KERMIT, and a reasonable assortment of PC-DOS applications.

We have no experience with the PC-AT/370, but is is now available and looks to be a significantly more powerful system than the PC-XT/370.

THE UC BERKELEY CONNECTION

We have found the consulting staff at Berkeley very helpful and informative. They had a PC-XT/370 at one time, but that machine has now been modified to a 3270/PC and is no longer available. In order to make things as simple for yourself as possible, try to locate software that is written in standard FORTRAN (77 OR 66) with minimum nonstandard language and system calls. If the software is already running on a VM/CMS system, it should be very easy to make it run under VM/PC. If not, IBM still provides a great deal of upward compatibility in its operating systems, so there is a good chance that packages written for the IBM OS/370 batch environment will run. This is especially true of straight FORTRAN applications without assembly-language features. Berkeley programming consultants have been very helpful in determining and solving problems in this area.

If the software is sent to you on tape, you must bring or mail the tape to Berkeley and have it loaded, using an account number that you set up there. Once the file is on the mainframe, it can be downloaded onto your XT/370 by modem, if the file is relatively short, or by direct connection with the Berkeley mainframe. Downloading by the latter method, of course, requires a trip to Berkeley.

SUMMARY

We have successfully implemented load-flow analysis on the IBM PC-XT/370. This involved obtaining a large program written specifically for the IBM/370 mainframe and adapting it for use on the PC-XT/370. Our procedure was straightforward and the results we have obtained have been excellent.

The procedure described here is useful for adapting a large number of mainframe IBM System/370 programs to run on the PC-XT/370, and yields a very powerful computational tool at a very attractive price.

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Bill Lahl, IBM Oakland Office, 464-5047

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1. O. I. Elgerd, Electric Energy Systems Theory: An Introduction (McGraw Hill, New York, 1971).

2. IBM Announcement Letters October 18, 1983, July 17, 1984. Available from Bill Lahl, IBM Oakland Office, Oakland, CA.

3. Cosmic Software Catalog, NASA, The University of Georgia, Athens, GA 30602, NASA-CR-174576 (1984).

APPENDIX A: PER-UNIT SYSTEM

In electric power systems analysis, voltages and currents are commonly expressed in percent or per-unit[1-3] of rated values. The corresponding base for expressing per-unit impedances is the ohm, which would produce a voltage drop of rated or base volts per phase when rated or base current flows through the impedance. Angles are expressed in degrees, or radians, whichever is most appropriate.

The per-unit system is more convenient for several reasons:

1. Per-unit values are more meaningful and provide data that is more easily correlated.

2. There is less chance of mixups between phase and line voltages and single phase or three phase powers.

3. In the conventional form of calculation using volts and amperes, the solution of a system involving power lines of several different voltage levels requires all impedances that are to be added to be transferred to a common voltage level. In the per-unit system, the different voltage levels entirely disappear and a power network involving components operating at different voltage levels reduces to a system of simple impedances each interconnected in a common network.

4. Widely diverse components may have very similar per-unit values so they are easy to compare in a relative manner. For example, if a 1.0 per-unit voltage is applied to a 0.5 per-unit reactance, the current will be 2.0 per-unit regardless of the component rating.

The basic equations used in per-unit calculations are

$$V_{base} = I_{base} Z_{base}$$

$$V \cdot A_{base} = V_{base} I_{base}$$

Normally two of the four quantities are specified and the other two are then evaluated. Now, for example, say $I = 100$ amps and $I_{base} = 200$ amps. Then $I_{pu} = 100/200 = 0.5$ per-unit amps.

APPENDIX A REFERENCES

1. J. R. Eaton, Electric Power Transmission Systems (Prentice Hall, Englewood Cliffs, NJ).

2. W. D. Stevenson, Jr., Elements of Power System Analysis (McGraw Hill, New York).

3. O. I. Elgerd, Electric Energy Systems Theory: An Introduction (McGraw Hill, New York, 1971).