Case-Based Approach for Transient Analysis Modeling Using EMTP

A. Ibrahim, T. Niimura, J. R. Marti, H. W. Dommel
Department of Electrical Engineering
The University of British Columbia
Vancouver, B.C., Canada, V6T 1Z4

Abstract - **The Electromagnetic Transient Program (EMTP) is extensively used for simulating fast transient effects in electric power systems. However, the difficulty of proper modeling of target power systems remains a challenging problem for users. EMTP also requires a high level of technical expertise to apply models properly, but this expertise is normally personalized and not stored as electronically accessible information. This paper proposes a case-based support system for EMTP simulation. The support system is composed of three parts. First, the support system selects a base case from a case data base, to be modified to meet the user's requirement. Second, the support system checks the syntax and validity of the new case data. Finally, the EMTP solution is checked whether it is reasonable.**

Keywords: EMTP, case data, database, support system, data validation, results evaluation.

I. INTRODUCTION

The Electromagnetic Transient Program "EMTP" [1] is a widely used program for transient analysis, for both industry as well as in universities, in several versions. The program features an extremely wide variety of modeling capabilities encompassing electromagnetic and electromechanical oscillations ranging in duration from microseconds to seconds. The EMTP was originally developed at Bonneville Power Administration (BPA) in 1969 [2]. Since then, many improvements have been made to the program, both inside and outside BPA. The EMTP is reasonably well debugged, powerful, and flexible. However, the main drawback of the EMTP is its difficult user interface which limits the effectiveness and the usability of the program.

One concern with the application of the EMTP is the difficulty of selecting the proper models of power system elements for various types of studies. There are multiple choices of models of network elements now offered in the EMTP and the users must choose the proper models that best suit their purpose. Users must also be familiar with the format and the syntax of the EMTP input data to simulate a case. Moreover, users spend too many hours to correct and edit the data file until reliable answers are obtained. It is usually not convenient to go over the large volumes of manuals while working on a computer, especially for beginning users. Therefore, the users are assumed to have a basic knowledge of the phenomena to be simulated and the input format of the EMTP.

It is best to have an experienced EMTP user to overlook the initial stages of the EMTP learning curve. However, it is not always possible for the beginning user to have a supervisor who is familiar with both the procedures of EMTP simulation and the phenomena to be simulated.

Many efforts have been made to improve the user interface of the EMTP during the last years. The concept of an Integrated Engineering Simulation Environment (IESE) [3-5] was provided to simplify the user interface problem with the EMTP. This environment integrates a graphic oriented interface with a modular engineering database. The Data Modularization concept has been used in [6] to simplify the complex format of EMTP data input. A new approach was presented in [7] to use the MATLAB environment to develop a new EMTP. However, the execution time of MATLAB is much longer than that of the EMTP. ATPDRAW [8] was developed as a mouse-driven preprocessor to ATP, where the user can build up a circuit by choosing components from menus. For the DCG/EPRI version of EMTP, a graphical user interface is being developed by Ontario Hydro, Canada. Although the ease of using the program may be solved by the above mentioned techniques, such as graphic displays and data modularization, the difficulty of proper modeling of target power systems remains basically unchanged. Also data validation and data sanity checks have not yet been fully implemented in the EMTP.

This paper describes the development of an expert system to support engineers and students in the proper use of the EMTP.

II. THE SUPPORT SYSTEM STRUCTURE

The overall structure of the EMTP simulation expert system is shown in Fig. 1. This expert system is composed of three stages. In the first stage, the support system selects a base case, which closely resembles the user's case, from a case data base. After the user has set up his/her own specified case data, the expert system checks the syntax and validity of the new case. In the final stage, the EMTP solution is obtained and checked whether it is reasonable. For example, zero sequence circuits at higher frequencies may indicate that a frequency-dependent transmission line model is needed; higher frequencies in a source Thevenin equivalent circuit may indicate that a frequency-dependent equivalent circuit is needed, etc.

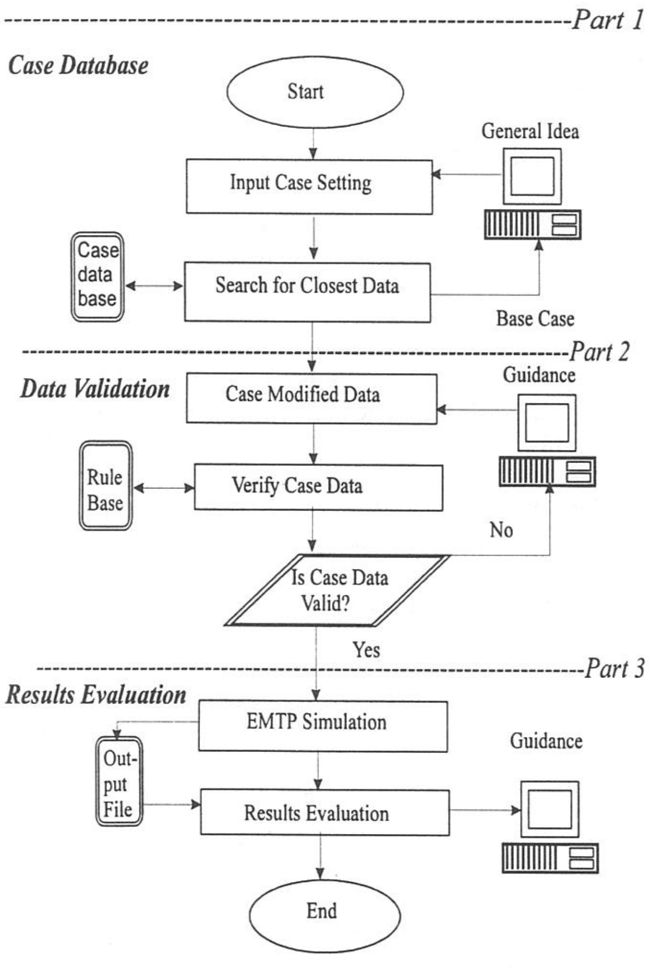


Fig. 1. Structure of EMTP support system

A. The Case Database

Building the case data that contains a collection of various power transient study cases is the most important part of the proposed expert system. These cases are collected from EMTP expertise, papers, and manuals. The case database locates the case data set that is closest to the system configuration and type of study of the user's target case.

This operation is done through a search tree menu index that contains all cases. The divisions in the search menus are classified so that the user can reach a relevant data case easily. The user chooses the layered menu of the keywords by a point-and-click operation of the mouse, then in the bottom layer of the search an example of an analysis, with the network configuration and brief comments being displayed. Fig. 2 shows the search tree of the case data for the preliminary implementation of the prototype support system.

The final selection of the case data by the user initiates the support system to retrieve the data necessary for running the EMTP simulation, and to copy to the user file with a message about the location of the file and the file name. In the next step the user can modify the case data to meet the requirements of the specific case to be studied.

B. Data Validation

In the second stage, the modified case data will be similar to the original case data but not identical. The support system checks the structure and the validity of the new case data that the users modified for their specific purposes. The support system will give the user some guidelines and explanations to correct suspicious data. Also some hints about the system description are provided.

The data validation process represents the sanity checking of the input data file. Such a checking will include the reasonableness of the data, the frequency range over which the models are valid, the time step " Δ t", the length of time "Tmax" to be simulated, and other features.

From the knowledge of different models of power system elements and the phenomena being studied, certain rules will be created for the support system and applied to verify the validity of the case data. For example, the nominal pi circuit transmission line is only recommended for low frequency transients (a few hundred Hz), and only if zero sequence currents in that line are small: From this information we can write some rules for the support

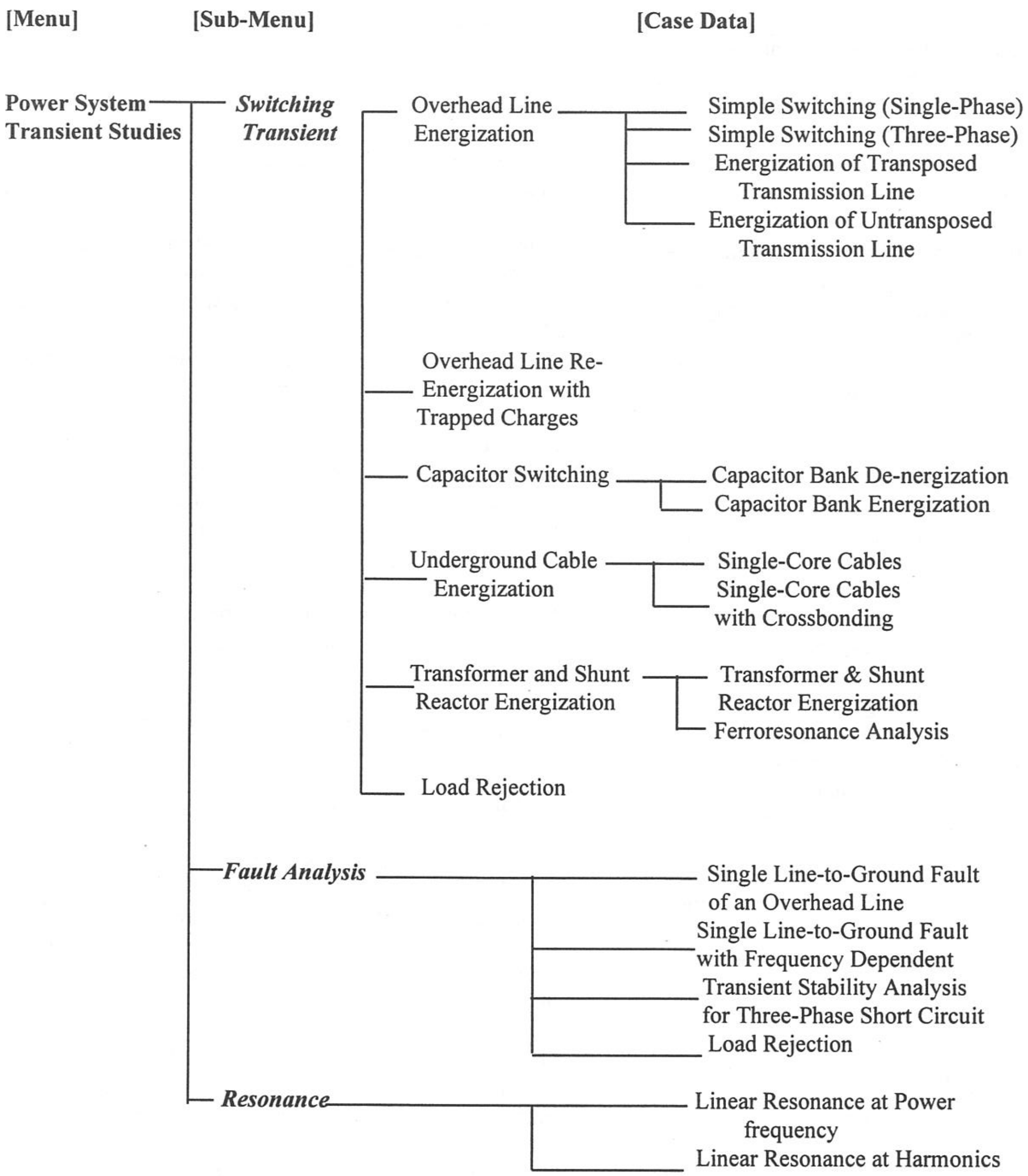


Fig. 2. The search tree case database

system to check whether the pi circuit model is the proper selection for the specific case.

At the end, if the support system finds that the modified case data is valid, it will activate EMTP to simulate this case. If not, the same procedure will be repeated until the proper case data is obtained.

C. Results Verification

Finally the results verification step is executed, where the EMTP solution of the target system is checked whether it is reasonable. The most important tool for verifying the EMTP case results is the basic knowledge of the phenomena to be simulated. Field test results [9], technical papers, textbooks [10,11], and EMTP expertise are the sources of this knowledge. The following check points are useful for implementing the support system results evaluation task of the EMTP output [12]:

1. The steady-state phasor solution can be checked for bus voltage magnitudes at locations where load flow results are available, and for injected source currents and power, and MW/MVAR loads.
2. Line and switch currents should be balanced at transposed lines.
3. If there is a message warning about a nonlinear inductance operating outside the linear flux region, adjustment should be made in the initial conditions.
4. Machine model steady- state printouts should be checked for speed, terminal power, field current and air gap torque levels in the steady state.
5. Pre-switching steady state wave forms should be examined for characteristic harmonic contents, which should reach a stable condition before transients are initiated. Also, the wave form shape of the simulated case can be used to verify the results. For example, ferrorsonance wave forms typically have rectangular shapes.
6. Transient frequencies according to $f = 1/(2\pi\sqrt{LC})$ for lumped L-C circuits, $f = 1/4\tau$ for open-circuited lines and cables, and $f = 1/2\tau$ for short circuited lines and cables. Where τ is the traveling time.
7. The lumped circuit surge impedance, $Z = \sqrt{L/C}$, is useful for relating transient voltage and current peak magnitudes in lumped circuits.
8. The traveling wave reflection and transmission coefficients can be used to check behavior of the traveling waves when they enter stations.
9. Damping rates of lines and cables, transformers, and series RL loads are generally low, especially at high frequencies.

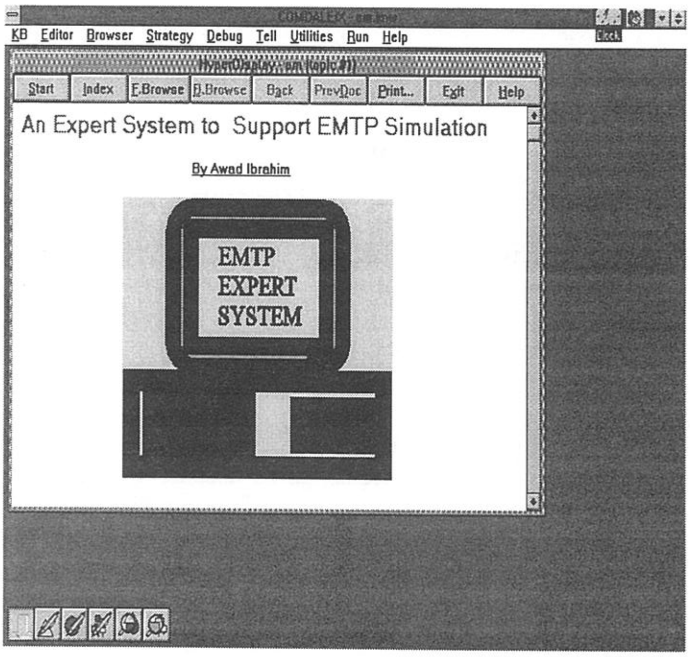
One example of checking the reasonableness of the solution is to obtain the frequency domain results for the target system and its reduced model. The target system can be simplified by a Thevenin equivalent or Frequency Dependent Network Equivalent (FDNE). The FDNE models has been used in previous work [13,14]. These FDNE models consist of simple RLC branches, whose values can be calculated using the resonant frequencies of the original system. The FDNE model will have the same behavior of the original system over a wide range of frequencies. The results can be evaluated by the aspect of having good matching for the wave forms of the actual system and its FDNE model in the frequency domain. These results will give useful information about the resonance frequency impedance.

The support system will propose a list of possible reasonableness checks to the user so that he can correct his case data.

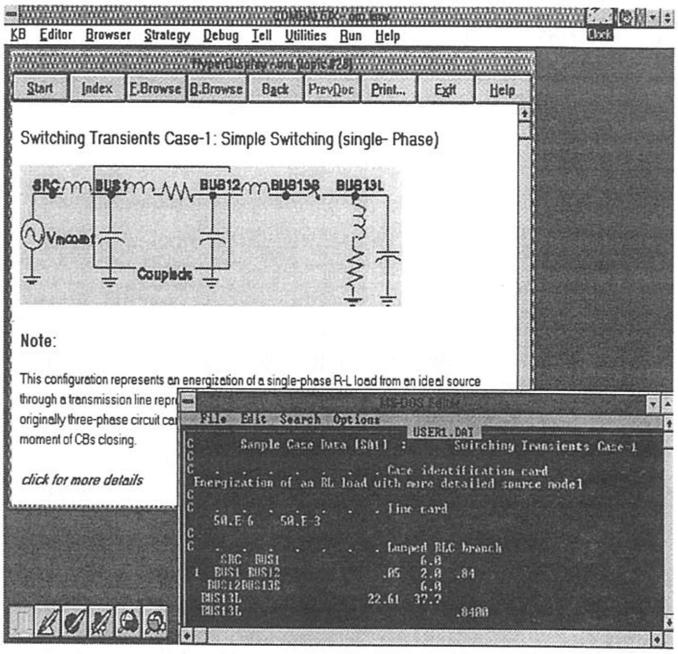
III. SYSTEM IMPLEMENTATION

At this time, a prototype case database has been implemented to support EMTP simulation. The EMTP support system currently has the case data shown in Fig. 2. The EMTP version of UBC "MicroTran" [1] is used to run the data cases [15] of the case database, interfaced with the support system. An expert system shell named COMDALE/X [16] is used to build up the knowledge base of the prototype EMTP expert system.

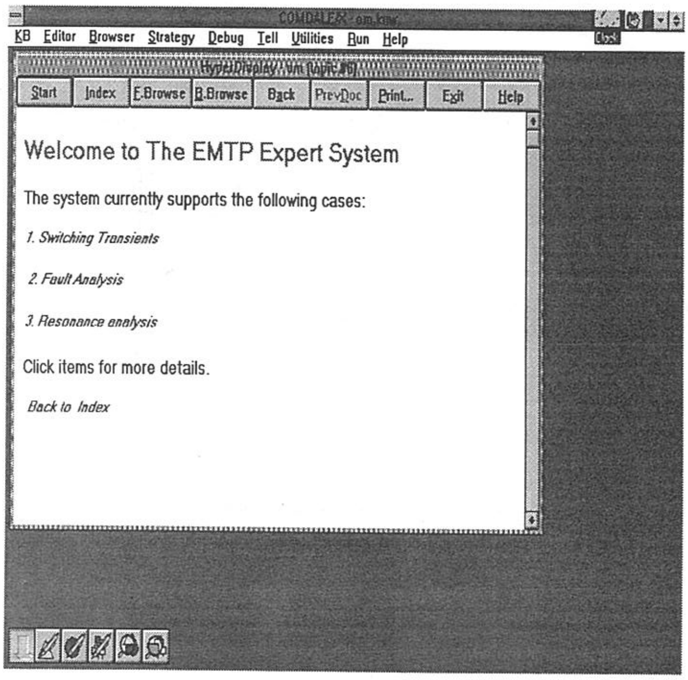
This prototype support system is installed on PC 486-100 MHz running on Windows 95. Fig. 3 shows an example of the support system simulation. Each case data is described by some information; this information is organized so that the user can look at a picture and short description. If the user wants more information about the case, he can jump to a detailed description. The final selection of a case data by the user will give the user the choice of selecting this case data as the desired one or modifying this case data.



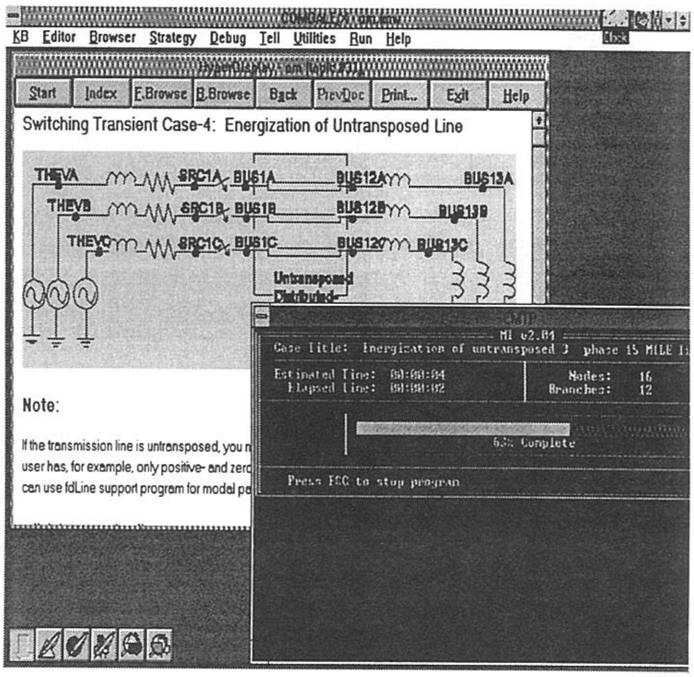
(a) Opening Window



(c) Case data and description



(b) Main Menu



(d) EMTP being executed

Fig. 3. Sample hard copy of the support system

IV. CONCLUSION AND FUTURE WORK

This paper describes an EMTP simulation support system which allows the users to choose the closest data from the past simulation cases, and based on such data, to modify these cases to meet the user's particular targets. The following are anticipated for future work:

The case database can be expanded to include more important case data from different power system transient studies. Also a new case database that contains the different EMTP representations for various models of power system elements will be implemented. This case database will solve the problem of selecting the proper model based on certain rules according to the problem properties of the system. Each EMTP element type is stored in a separate file. These components will be extracted and assembled in one file that can be directly used by the EMTP. The data validation and results evaluation will be applied to a specified power system transient study such as fault analysis or switching transient in order to give the user some checking expertise for the overall picture of the simulated system.

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