Development of Data Translators for Interfacing Power-Flow Programs With EMTP-Type Programs: Challenges and Lessons Learned

Task Force on Interfacing Techniques for Simulation Tools

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***Abstract*—This paper describes the challenges and lessons learned when developing industrial-grade data translators aimed for the interfacing of power-flow programs with Electromagnetic Transients Program-type programs. It has been found that the greatest challenges to overcome include: 1) the lack, in the databases used in power-flow programs, of vital pieces of information necessary to perform transient studies; 2) inconsistency in the format of data files; 3) the presence of data entry mistakes in very large databases; 4) the validation of the translated data; and 5) the analysis of the large amount of data that transient simulations provide. Several examples are presented to show the implemented solutions. Finally, recommendations based on experience are made to help future developers of interfacing tools.**

***Index Terms*—Electromagnetic transients, Electromagnetic Transients Program (EMTP), power flow.**

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I. Introduction

TIME domain simulations of large power systems using EMTP-type programs are becoming increasingly common. The need for electromagnetic transients programs is indispensable due to the requirement of a detailed model of control systems and nonlinear network elements. The push comes from the smart grid technologies that require a large number of switching operations for economical or reliability reasons [1]. The pull comes from the continuous increase of computing power that has made possible the simulation of electromagnetic transients of large power systems [2]–[4].

The objective of the translators is to perform automatically the data conversion between two different databases [5]–[8]. In many utilities, the available data are in power-flow program formats (e.g., PSS/E). Therefore, data translators are required to convert the power-flow program files to appropriate formats for EMTP type of programs. Several translators that have been developed in this work are intended to convert input data from power-flow (PF) programs into EMTP-type programs.

An effective technique for building and maintaining time-domain models of large networks in the EMTP-RV was reported in [3] and [4]. This technique is based on an automatic translation of text data into a graphical user interface (GUI) model using scripting (JavaScript). It was shown that the resulting model of the network can serve as a unified framework for different types of power system studies. Frequently, transient analyses are required to supplement other studies for the investigation of electrical networks.

In [6], PSCAD/EMTDC is linked to PSS/E through E-TRAN. E-TRAN is a translator that performs a direct data conversion between phasor-based power flow and stability simulation tools and electromagnetic tools. E-TRAN can initialize the machines and sources in PSCAD simulations based on the translated data from the power-flow analysis in PSS/E [6], [9]–[11].

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An alternative method applicable to very large distribution networks was presented in [2]. The process of model derivation is fully automated and involves translation of input text files extracted directly from databases into EMTP-RV netlists using a MATLAB script. The proposed technique has been successfully applied to various electrical distribution networks resulting in very accurate three-phase time-domain models. Similar methodologies have been used to translate data from the proprietary power-flow to ATP [12], from EMTP-RV to ATP [13]–[15], and from ATP/EMTP to OpenDSS.

The data translator allows an electric power utility to perform calculations of overvoltages and other transients using the power-flow database complemented with additional data. In particular, power distribution utilities can perform EMTP simulations for the calculation of overvoltages due to faults and backfeeding, capacitor switching, ferroresonance, inrush currents, DG penetration, and to corroborate their smart grid technologies on full networks that have many switching operations for network re-configuration.

In this paper, one-way data conversion has been developed from proprietary and royalty-free (OpenDSS [16]) power-flow programs, into EMTP-RV [17], and into ATP [18]. The paper presents the challenges and lessons learned when developing industrial-grade data translators aimed for the interfacing of power-flow programs with EMTP-type programs.

The rest of the paper is organized as follows: Section II discusses the translation process form a power-flow program to EMTP-RV. Section III gives the example on the necessary work for translating transmission lines. Section IV discusses the challenges associated with power flow to EMTP-type program translators. Important challenges are to validate and analyze the results obtained by the generated EMTP models. The validation process for a simulation example is elaborated in Section V, including the steady state and transient validation process. In Section VI, important recommendations for the future developers of translators are highlighted and finally, Section VII concludes the paper.

II. Power-Flow to EMTP-RV Translator

EMTP-like programs regularly use a code written in a high-level descriptive language as an input for time-domain simulations. This code is called a netlist. Before the time-domain simulation starts, all models developed with the graphical user interface are converted into the netlist. Although the GUI of the EMTP software has a complex multi-layer structure and can be used as a unified framework for different power system studies, development of the models for very large networks cannot rely only on this tool. Indeed, it is impractical to build the entire model having hundreds of thousands of branches and nodes using only mouse-based functions of the GUI. In such a case, a scripting approach should be used. An automatic script can create the network model from the input text files within a relatively short period of time. An alternative is the use of dynamic-link libraries (DLL). It seems possible to link a DLL to custom models. However, this has not been attempted in this paper because of the large variety of the custom models needed. It was estimated that the development of custom DLLs required more human-hours than developing GUI-based models. Another option, not explored in the paper, is to have hybrid solutions, that is, GUI combined with ASCII defined blocks/subnetworks.

Power systems consist of a very large number of similar elements. If a model of some particular element does not already exist among the built-in blocks of EMTP type of program, it can be built in the graphical user interface. To translate the power-flow data into a netlist, the detailed prototype models for each group of the network elements were developed first using the GUI. Then, each one of the prototype models was converted into a short netlist which textually describes a particular type of the network elements. Applying this technique, the following prototype models were derived:

- area substation transformer with tap changers;
- circuit breakers;
- overcurrent protection;
- overvoltage protection;
- undervoltage protection;
- directional power protection;
- directional overcurrent protection;
- network transformers;
- network protectors;
- unit substation transformers;
- intermittent energy resources.

In addition, some of the built-in EMTP models were adopted. They are:

- PI-sections;
- grounding zigzag transformers;
- RLC branches;
- ideal switches;
- electrical loads;
- synchronous machines;
- induction machines.

The netlists of the custom prototype models and those of the relatively complex built-in models (such as the synchronous and induction machines) were placed together in a separate library folder.

The data used by the power-flow to EMTP (PF-EMTP) translator are included in 27 different types of the text files. These files describe connectivity, ratings, specifications and, in some cases, the geographical location of the network elements. The source database is very large since it contains more information than what is necessary for power-flow studies. Therefore, the information needs to be filtered to extract only the significant data. On the other hand, the source database does not contain all the information needed to perform time-domain simulations. The missing information frequently comes from different databases, datasheets and even from field inspections. The following parameters can be mentioned:

- Nonlinear magnetizing curves of all the transformers (network, unit substation, high-tension customers).
- Individual relay settings for overcurrent, overvoltage, undervoltage, and reverse power.
- Individual settings of the network protectors.

The PF-EMTP translator has been implemented in MATLAB. The software has been chosen due to its built-in capabilities of dealing with different types of variables. Frequently the translation process involves some calculations, mostly for unit conversion. A flowchart of the translation is shown in Fig. 1. As shown, the process of model assembly is fully automated and involves translation of input text files extracted directly from the databases into a netlist.

As it can be seen in Fig. 1, the translation starts by reading the power-flow and supplementary files (Blocks 2 and 3). Using these data, the parameters of the network elements are calculated in Block 4. Block 5 checks whether the prototype model exists in the custom model library. The syntax of the simple built-in models, such as an ideal switch, a PI-section and a constant power load, are not stored in the library but written directly into the netlist as shown in Block 6. For the more complex models, their prototypes are read from the library and copied into the netlist after all the parameters of the particular network element are updated (Blocks 7 and 8). The result of the POWER-FLOW to EMTP data translation shown in Block 9 is a text file describing the entire power system.

The work reported in this paper links two PF programs with two EMTP simulators. At the present stage, a one-way data conversion shown in Fig. 2 is considered. In this figure, Blocks 1 and 2 correspond to the proprietary and commercial software whereas Blocks 3 and 4 are royalty free platforms. The main databases are related to the power-flow program of Block 1. Due to the space limitations, most of the discussion is devoted to the PF (power-flow) to EMTP translator described in the previous section.

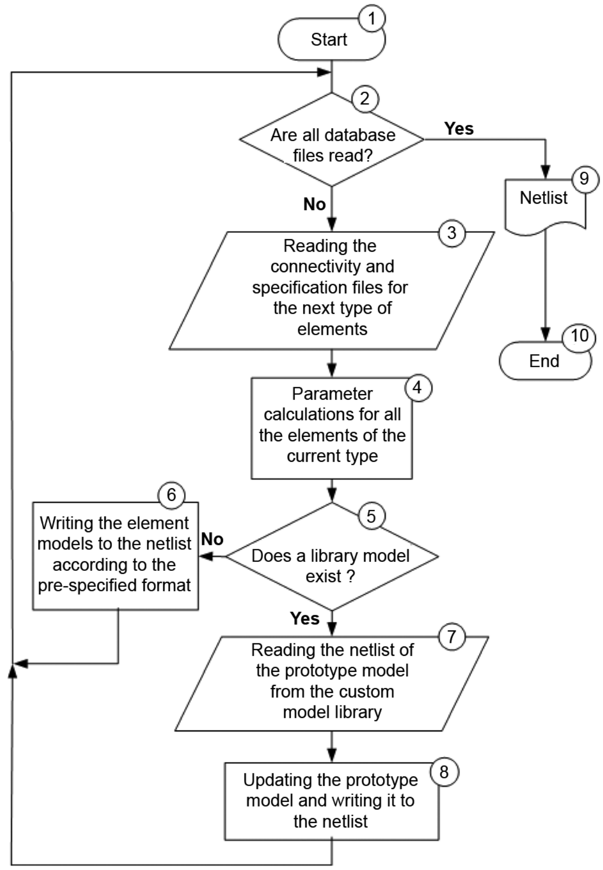

Fig. 1. Flowchart of the data translation from a power-flow database to EMTP.

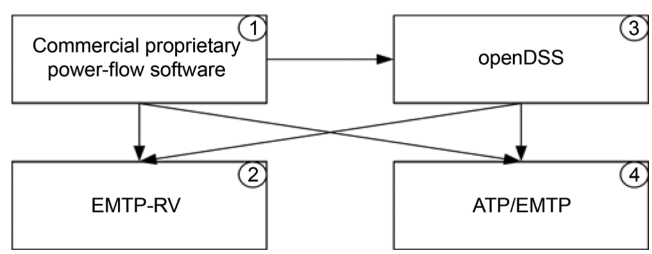

Fig. 2. Scheme of a one-way power-flow data translation.

III. Example

An example on the translation of the transmission line information (feeder sections) from the source databases into the EMTP netlist is presented. The information on connectivity and impedance specifications is contained in separate files. Fig. 3 shows one data line of the connectivity and the specifications files.

One can see that in the connectivity file, in addition of the information on the "from" and "to" nodes and the length of the section, there is also information on cable rating. In the specifications file we find the positive and negative sequence impedances and the line charging. The translator needs to perform, in addition to operations for unit conversion, calculations to compute phase quantities from sequence quantities. The following formulas are utilized to compute the phase impedance matrix:

$$Z(\Omega) = \frac{Z\left(\frac{m\Omega}{kft}\right).\text{Cable length(ft)}}{1{,}000{,}000} \quad (1)$$

$$Z_S = \frac{(Z_0 + 2Z_1)}{3} \quad (2)$$

$$Z_M = \frac{(Z_0 - Z_1)}{3} \quad (3)$$

$$\mathbf{Z}^{abc}(\Omega) = \begin{bmatrix} Z_S & Z_M & Z_M \\ Z_M & Z_S & Z_M \\ Z_M & Z_M & Z_S \end{bmatrix}. \quad (4)$$

IV. Challenges

The development of reliable data translators for large-scale power systems faces a number of technical and organizational problems, which are discussed in this section.

A. Inconsistencies in the Format of Source Data Files

Nowadays, the power industry lacks a unified representation of the network and device data. Although some standards were suggested in the area [19], [20], they are not widely adopted in commercial applications. In addition, different stakeholders in the industry design their databases for their particular needs. As a result, serious issues with data exchange arise even within one organization using different software tools or considering adopting a new one.

It becomes extremely hard to maintain synchronized and consistent data in numerous databases at different locations. Moreover, data formats of two versions of the same software can be incompatible. For example, E-TRAN only generates files compatible with PSCAD version 4.2.1. Users of PSCAD version X4 have some difficulties using the generated data by E-TRAN if the substitution library feature of E-TRAN is used [11]. The substitution library allows the users to employ detailed models

Connectivity File:

From	To	Spec	Length [ft]	Number of Conductors	Normal Rating [A]	Emergency Rating [A]	Under Observation
SW12	M59504	7405XJ	115	2	690	1051	U

Specifications File:

Spec	Nominal Voltage [kV]	Positive Sequence Resistance [mOhm/kft]	Positive Sequence Reactance [mOhm/kft]	Zero Sequence Resistance [mOhm/kft]	Zero Sequence Reactance [mOhm/kft]	Charging Reactive Power [kVA/kft]
7405XJ	13.406	16.2	31.2	203.6	70.9	11.1

EMTP Netlist:

```
_PI;PI1a;6;2;SW12a,M59504a,
3,1Ohm,0,1mH,0,1uF,0,1,1,1,1,          } connectivity
_PI;PI1b;6;2;SW12b,M59504b,
_PI;PI1c;6;2;SW12c,M59504c,
0.00904667 0.00718367 0.00718367
0.00718367 0.00904667 0.00718367       } resistance
0.00718367 0.00718367 0.00904667
0.01355425 0.00403679 0.00403679
0.00403679 0.01355425 0.00403679       } inductance
0.00403679 0.00403679 0.01355425
0.01884045 0.00000000 0.00000000
0.00000000 0.01884045 0.00000000       } capacitance
0.00000000 0.00000000 0.01884045
0.00000000 0.00000000 0.00000000
0.00000000 0.00000000 0.00000000       } initial conditions
0.00000000 0.00000000 0.00000000
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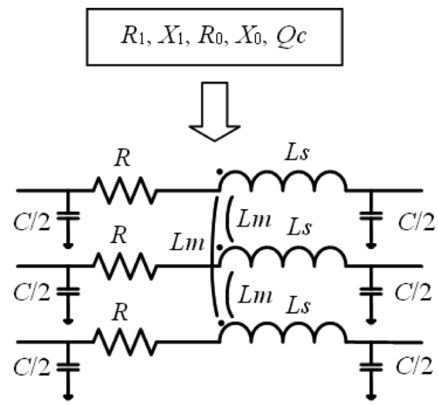

Fig. 3. Example of the conversion of a transmission-line section from the power-flow databases into the EMTP netlist.

instead of simple power-flow-based models in PSCAD. Therefore, the present approach to the power system data exchange is based on various translators developed per application [21], [22].

B. Data Entry Mistakes and Missing Data

Even the large databases, containing tremendous amounts of power system elements, are rarely complete. Indeed, they describe systems that persistently change over time intervals. In these databases, human mistakes are not easily identifiable, especially when instead of halting calculations in case of missing or incorrect data, the software continues execution using some default values. It should be noted that, sometimes, not all the substitutions are reported. This approach is advantageous in the short term. However, in a long run, it may lead to serious discrepancies between the model and the actual system. Therefore, one of the requirements to the data translators is their capability to verify integrity of the input and output data in the original application.

C. Insufficient Data in the Source Databases To Perform Transient Studies

Accurate three-phase time-domain modeling of electrical networks requires much more information than a traditional power-flow program. Sequence impedances, tap changer scheduling, types of protective relays and their settings, transformer magnetizing curves, etc. must be known. However, this information may not be at hand in the deregulated power markets. To solve this problem, data exchange among different utilities and among utility and large independent customers is required. In some cases, it implies necessity of coordinated equipment surveys in the field.

D. High Computational Demands

Three-phase time-domain simulations are considerably more demanding in terms of computational resources than power-flow calculations. This becomes a critical point when extra large networks are modeled with a very high level of details. In such a case, the number of sub-circuits, stack, and necessary memory can be far beyond software and hardware limitations. In addition, a time domain solution may also fail without accurate prediction of the system matrix sparsity. Therefore, at the early stages of the translator development, it is highly desirable to estimate the above mentioned parameters and adjust the models according to the limitations. In this work, upon our request, the developers of the EMTP-RV have provided us with a significantly enhanced release of the software. This allowed for a successful simulation of an extra large power system. The size of its EMTP-RV model is given in Table I. For ATP/EMTP, we successfully used the available Giga version [23], [24].

E. Validation of Translated Data

Finally, in parallel with the translator, it is very important to develop tools for validation and analysis of the results obtained using the generated EMTP models. These models cannot serve as a reliable source of information until it is proven that they provide results similar to some standard software and/or field measurements. The comparison involves hundreds of thousands of different parameters and must be automated. A process of validation is described in the next section in more detail. Due to the

TABLE I
NETWORK DATA SUMMARY

Name	Number of elements
Control-system signals	592,857
Network devices	674,027
Network nodes	87,263
Size of the main system of equations	104,825
Actual number of non-zeros	787,089
Number of data lines	2,124,726

size of the input and output data, manual processing of system-wise results is impractical. Instead, an automated approach employing custom computer codes should be used. Among others, it shall include waveform processing, statistical techniques, and graphical visualization. Following these guidelines, the translator developed in this work was used in the following fully automated studies: 1) symmetric and asymmetric faults with and without distributed generation; 2) impact of distributed generation on the voltage profile in distribution networks; and 3) automatic network reconfiguration and self-healing of the distribution networks.

V. MODEL VALIDATION

A. Validation Stages

Transient analysis is usually carried out to supplement different steady-state techniques that cannot capture complex interaction among different power system components in the time domain. Therefore, the EMTP model should not only provide results similar to those of the power-flow program but accurately reproduce real-life dynamics of the network.

It should be noted that the power-flow simulation is a complex linear algebra process based on the fundamental phasor solution. EMTP-type programs are based on the solution of differential equations. Using the proper integration step, the EMTP solutions are quite accurate at nominal frequency (50 or 60 Hz). The small discrepancies between the steady state solutions by EMTP-type programs and commercial power-flow programs may be due to differences in the representation of loads, which are normally considered constant $P-Q$ in power-flow programs and become constant impedance in time-domain simulations. This effect can be reduced by obtaining the $R-L$ equivalent circuit representing the load from the power-flow solution. Another reason for the discrepancy may be the modeling of non-linearities, for example, transformer saturation in the EMTP, which is not commonly considered in power-flow simulations. Discrepancies can also come from differences in the modeling of electromagnetic unbalances (non-transposed conductors in transmission lines), which are not captured by the use of sequence quantities in power-flow programs [25]. This is not a problem in the present paper because phase domain impedances are obtained from sequence quantities.

To ensure the correctness of the model the following validation steps were taken: 1) comparison of EMTP steady-state solutions against results obtained using a commercial power-flow program for peak, light load conditions, and single and double contingencies. The differences found in node voltages and section currents were very small. For example, voltage differences of only a few tenths of a percent were found; 2) comparison of several three-phase short-circuits results obtained with the EMTP and with the short-circuit computation facility of the commercial power-flow software. Very small differences occurred in almost all feeders. There were some relatively large differences in feeders carrying very small currents, but they are negligible in absolute value; and 3) experimental validation of the generated EMTP models was carried out comparing the simulation results with recordings of several actual transient events that took place in different power systems. The simulation output has been compared with electrical signals recorded at the secondary side of the area substation transformers by the PQ Node hardware [26] and processed in PQ View software [27]. A small sample of the validation stages are presented below.

B. Steady-State Validation

The steady-state validation is an integral part of the PF-EMTP translation. Indeed, once a netlist of an extremely large network is generated according to the steps described in Fig. 1, it is necessary to verify that the configuration of the network and its parameters did not change, and the results are in line with the power-flow. The validation of the generated EMTP model is carried out automatically as shown in Fig. 4. After generation of the netlist (Block 5), the translator starts a time-domain simulation (Block 6). The simulation results are analyzed and written into various report files in Block 7. Block 8 reads the output data of the power-flow run (Block 9) and compares them with those of the EMTP simulation. At this stage, connectivity of the system, branch impedances, currents, and node voltages are checked. Finally, the comparison results are written into the text files (Block 10).

The results of the steady-state validation for three different power systems of different sizes and operating at peak loading are shown in Figs. 5–10. As it can be seen in Fig. 5, for more than 70% of the primary feeder sections, the results of the power-flow and EMTP calculations differ by less than 0.1 A and less than 1% relatively. The largest absolute error is 1.15 A which is 12.9% of the relative difference. The maximal relative difference of 58.2% corresponds to the negligible current difference of only 0.05 A.

As shown in Fig. 8, more than 40% of the secondary sections have the absolute error below 1 A and the relative error below 1%. The largest absolute error is 1.33 A which corresponds to 3.5% whereas the largest relative error of 9.2% is equivalent to 0.03 A in the absolute scale. The largest relative difference of all node voltages in the small-size network is negligibly small: 0.005%. Similar information for the other two networks is summarized in Table II. The small differences are attributed to the following reasons: 1) numeric inaccuracy of the specific database impedances used for the netlist generation; 2) the display of few significant digits in the power-flow results of the commercial software; and 3) slightly different approaches in modeling. The results obtained for the light loading cases also prove the validity of the derived dynamic model. They are not presented here for the sake of brevity.

It is necessary to mention that there are important differences in the way the loads are modeled in time-domain and

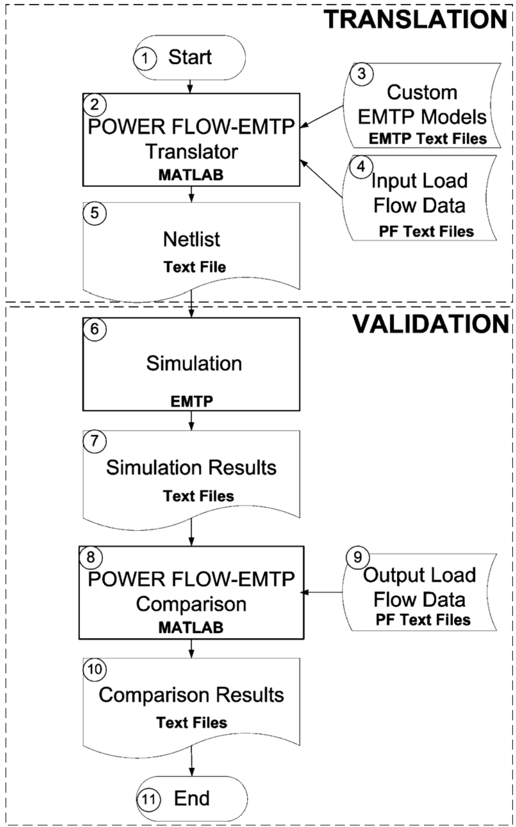

Fig. 4. Block diagram of the POWER FLOW-EMTP translator.

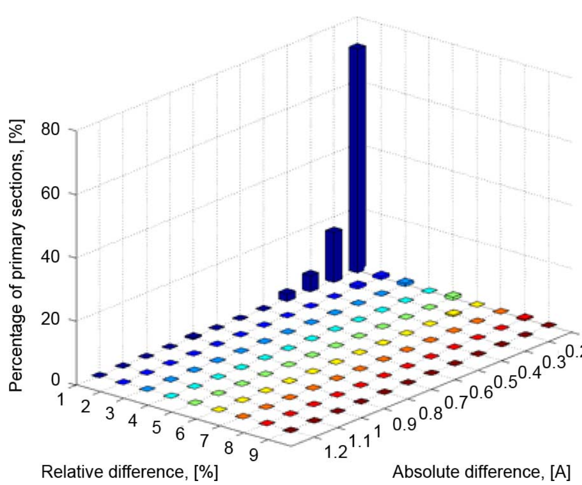

Fig. 5. Comparison of primary currents in a small-size network calculated using the commercial PF program and EMTP time-domain simulator.

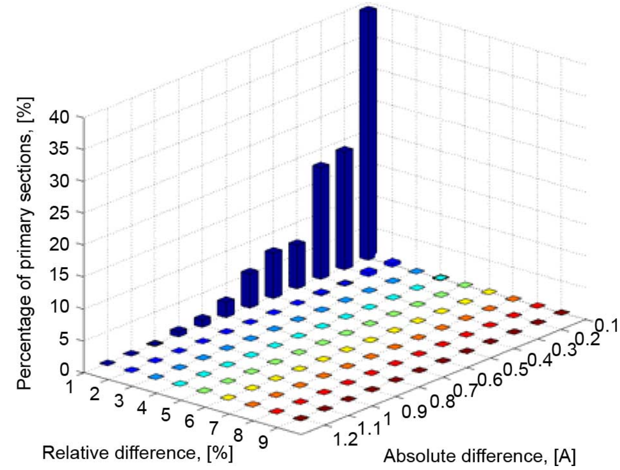

Fig. 6. Comparison of primary currents in a middle-size network calculated using the commercial PF program and EMTP time-domain simulator.

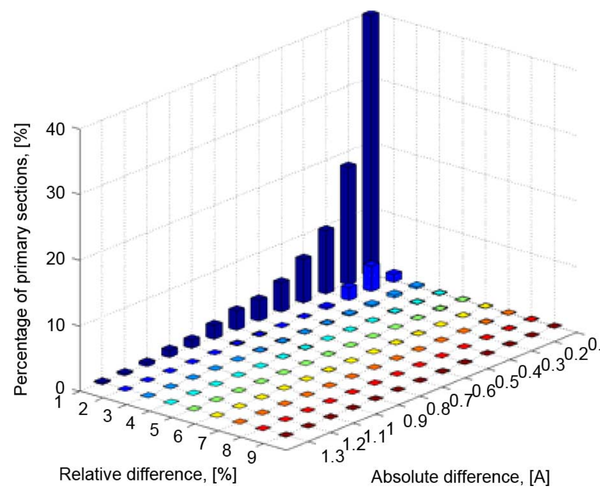

Fig. 7. Comparison of primary currents of a large-size network calculated using the commercial PF program and EMTP time-domain simulator.

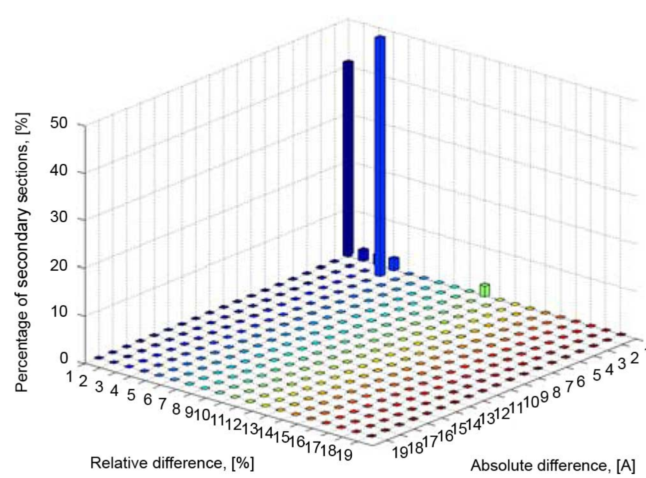

Fig. 8. Comparison of secondary currents in a small-size network calculated using the commercial PF flow program and EMTP time-domain simulator.

power-flow simulations. In power-flow simulations, loads are represented as constant power $(P-Q)$, whereas in time-domain (EMTP) simulations loads become constant circuit parameters $(R-L)$. In this paper, a good match has been obtained between the two programs because for the time-domain simulations the loads were "adjusted" from the beginning to the known (from the power flow) voltage at their terminals. The development of an efficient constant power load model for the EMTP is of paramount importance as a deviation from the rated voltage may affect substantially the value of the load.

As it was mentioned previously, the validation of the EMTP simulation results against the output of the commercial PF program has been carried out for the cases of three-phase short-cir-

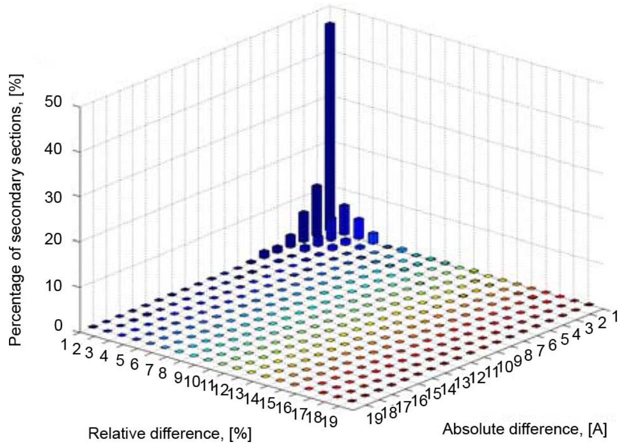

Fig. 9. Comparison of secondary currents in a middle-size network calculated using the commercial PF program and EMTP time-domain simulator.

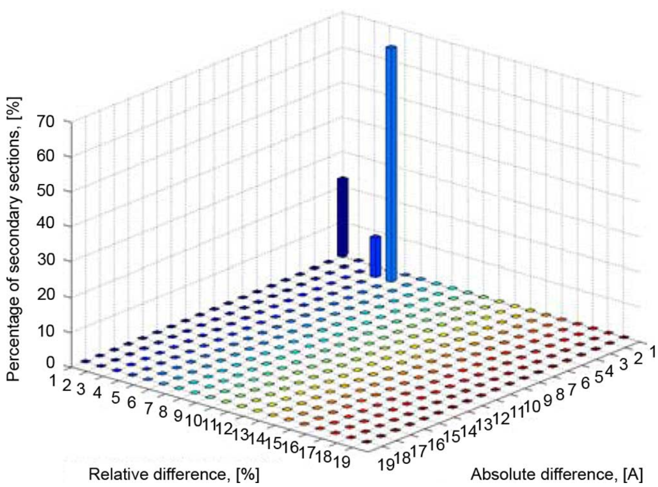

Fig. 10. Comparison of secondary currents of a large-size network calculated using the commercial PF program and EMTP time-domain simulator.

cuits in the primary and secondary subnetworks. For example, three locations shown in Fig. 11 were chosen to test the fault current levels in one of the primary feeders in the network. The comparison results are given in Table III. Similarly, the fault currents were assessed in cases of the three-phase short-circuits in the secondary subnetwork. The fault locations were chosen at service boxes and transformer vaults. The results for two of them are shown in Table IV.

C. Transient Validation

The transient validation of the EMTP model has been performed by comparing the numerical results with actual waveform recordings taken in the distribution networks during various faults. One of them is presented below. It consists of a single line to ground fault that has occurred at the terminals of a network transformer at the end of a 13.8 kV feeder shown in Fig. 11. This feeder is one of the 12 primary feeders connected to the 13.8 kV bus. A measurement unit is installed at the secondary side of an area substation transformer and records phase and neutral currents and voltages.

Based on the available measured data, the network loading used in the simulation has been adjusted in order to match the pre-fault conditions. The simulation starts at steady-state operating conditions. A single line-to-ground fault occurs in phase A at 34.5 ms. This fault is isolated after approximately six cycles by tripping the breaker of the corresponding feeder and opening all network protectors connected to this feeder. The simulation and measurement results are compared in Figs. 12–17.

From the waveform analysis, it can be concluded that the EMTP simulation has successfully reproduced the pre-fault, faulted and post-fault behavior at low frequencies and has captured the higher frequency oscillations as well. The simulations and the measured over-voltages, under-voltages and short-circuit currents match very well. For example, the first peaks of the simulated and measured fault currents have a difference of only 5.4% (3781.7 A versus 3997.2 A).

TABLE II
MAXIMAL ABSOLUTE AND RELATIVE ERRORS

Parameter	Unit	Network		
		Small-size	Middle-size	Large-size
Number of the network nodes	-	315	2,333	13,523
Maximal relative error in the node voltages	%	0.005	0.029	0.32
Number of the primary sections	-	217	1,041	3,965
Maximal absolute error	A	1.15	0.92	1.92
Corresponding relative error	%	12.8	0.58	0.28
Maximal relative error	%	58.2	3.45	41.8
Corresponding absolute error	A	0.05	0.06	0.03
Number of the secondary sections	-	44	1,375	11,543
Maximal absolute error	A	1.34	18	56.39
Corresponding relative error	%	3.51	0.98	2.46
Maximal relative error	%	9.15	18.13	69.53
Corresponding absolute error	A	0.03	0.64	1.48

TABLE III
COMPARISON OF THE TREE-PHASE SHORT-CIRCUIT CURRENTS IN THE MIDDLE-SIZE DISTRIBUTION NETWORK (FAULTS ARE IN THE PRIMARY SUBNETWORK)

Fault Location	PF Current, [kA]	EMTP Current, [kA]	Relative Difference, [%]
Beginning of the feeder	30.5	30.7	0.65
Middle of the feeder branch 2	19.3	19.7	2.07
End of the feeder branch 3	19.8	20.3	2.52

TABLE IV
COMPARISON OF THE TREE-PHASE SHORT-CIRCUIT CURRENTS IN THE MIDDLE-SIZE DISTRIBUTION NETWORK (FAULTS ARE IN THE SECONDARY SUBNETWORK)

Fault Location	PF Current, [kA]	EMTP Current, [kA]	Relative Difference, [%]
Service Box	14	14.5	3.57
Vault	81.4	84.6	3.93

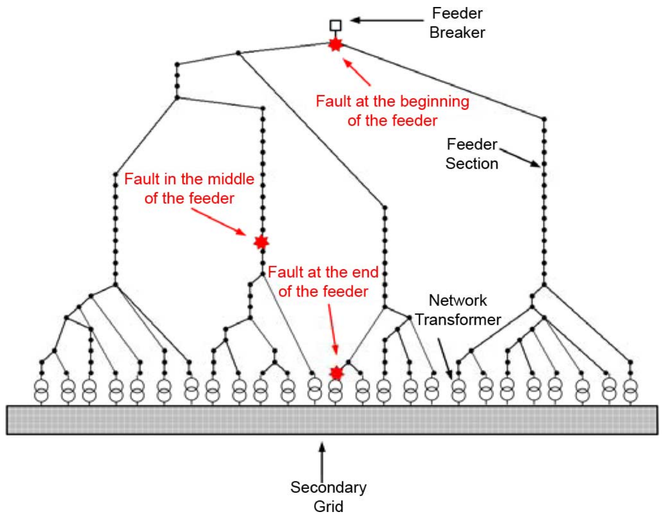

Fig. 11. Fault locations in the primary subnetwork.

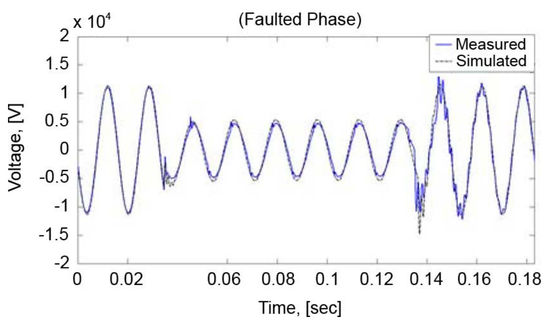

Fig. 12. Phase A (faulted phase) voltage at the secondary terminals of the area substation transformer.

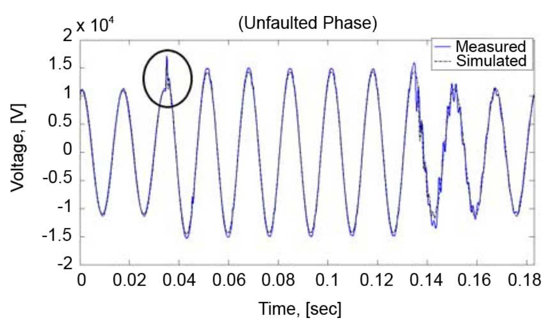

Fig. 13. Phase B (unfaulted phase) voltage at the secondary terminals of the area substation transformer.

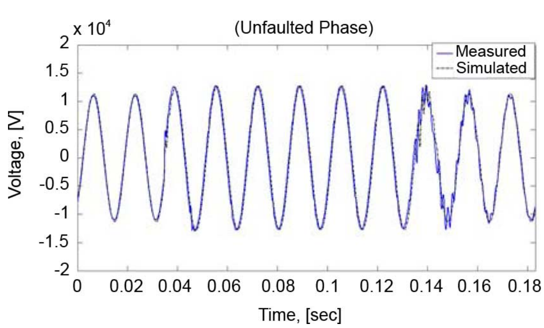

Fig. 14. Phase C (unfaulted phase) voltage at the secondary terminals of the area substation transformer.

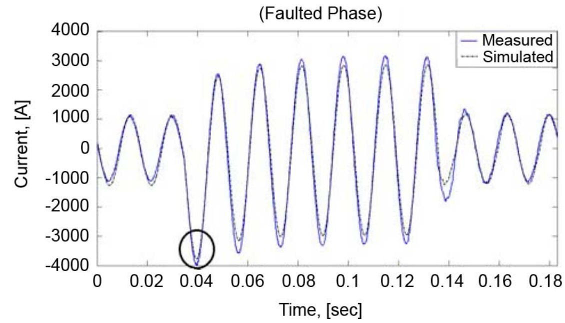

Fig. 15. Phase A (faulted phase) current at the secondary terminals of the area substation transformer.

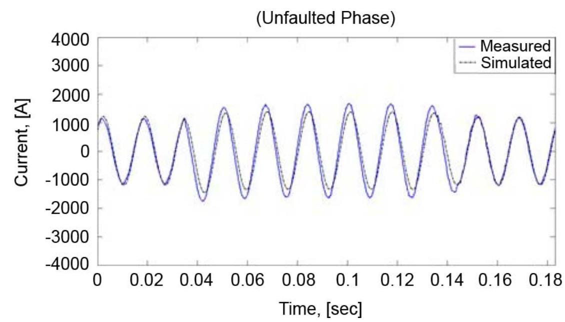

Fig. 16. Phase B (unfaulted phase) current at the secondary terminals of the area substation transformer.

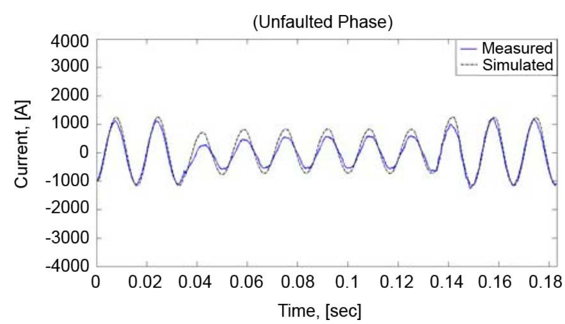

Fig. 17. Phase C (unfaulted phase) current at the secondary terminals of the area substation transformer.

VI. Recommendations

In this section the most important recommendations that the authors can make to future developers of translators are summarized.

A. Data Inventory

Before undertaking the translation task, it is recommended to make a complete inventory of the required data. Depending on the purpose of the time-domain study, some important pieces of information will not be available in the databases used for power-flow simulations. Essential information for transient studies, such as zero sequence impedances (or line configuration), are not part of a balanced power-flow program and therefore, frequently they do not exist in the source database. Many other important data may not be available in the power-flow database, for example, connection of transformers, magnetizing curves, under-load tap changers, relay protection devices and settings, arcing circuit breakers (with and without re-strikes), generators' and motors' electrical and mechanical data, surge arresters, grounding reactors, and so forth.

The biggest efforts and longest delays are attributed to the assembly and validation of a complete set of reliable data.

B. Multi-File Input—Single-File Output

Because of the above reasons, it is recommended that the PF-EMTP translator be capable of reading data from several databases. The alternative is to build a unified file from the source databases containing all the necessary information in a common file. Although the former option adds programming complications because the data come from different files, in the long-run, this seems to be a better way to gain access to multiple and varied databases. The latter process, merging all information in one file as input for the translator, was also experimented, but it increased the number of human errors and could not be easily generalized to other networks.

C. Data and Model Verification

Validation of each model independently and in the circuit is essential. The PF and EMTP-type programs may use different systems of units. To mention a few examples, we have found the following cases: impedances are given in Ohms per kilo-feet in the source database and they are needed in Ohms in the EMTP (see Fig. 3); magnetizing curves are in per unit at the source database and are needed in Webers versus Amperes in the EMTP. Frequently, the data archives do not exist in digital form and hand digitalization of the data is required. For these reasons it is recommended to validate each component model (unit testing) separately. This process starts by checking that the performance of each device complies with the specifications. For example, the standardized open circuit and impedance tests on the transformer models should be simulated on a standalone model before interconnection with the network. Similarly, a grounding transformer must deliver the specific positive and zero sequence reactive powers. Therefore, it is important to connect the model to a positive (and later to a zero) sequence source to ensure that the correct amount of reactive power is being demanded in each case.

D. Automated Data Validation

It is also recommended to create a computer code that automatically compares and validates the results obtained from time-domain power-flow (EMTP type) against the original phasor-based power-flow program.

Validation with field recordings offers the ultimate verification of the models. This, however, may not be easy to do in every case since experimentation with a real power system is not commonly done due to the high risks involved.

E. Automatic Postprocessing of Results

An important issue, that can be easily overseen when translating power-flow data into files for time-domain simulations, is that the required computing resources and tools for the analysis of the results are completely different. Power-flow simulations can be run for very large systems with relatively modest computer resources in a few seconds. Then, the user can analyze the rms voltages and currents (power flow) for hundreds of nodes or branches by inspection of tabulated results. Most commercial PF programs report the exceptions (over-current and or over- and under-voltages) for the convenience of the users. Many programs even produce colored one-line diagrams to help the user find where the problems are. On the other hand, time-domain simulations are traditionally performed for relatively smaller networks. Therefore, the computer resources and required effort for analyzing graphical (wave shapes) results are comparable to those of the power-flow case. However, when converting a large power-flow case into a transient case, the required computer resources increase considerably. Besides taking substantial simulation time to produce the results (seconds become hours), it is impossible to plot and analyze the wave shapes for thousands of signals (voltages, currents, etc.). For the large network presented above the results data file has 240 million lines! It is, therefore, recommended that an automated software facility be created to analyze the results. We remark that the currently available plotting facilities of both EMTP-RV and ATP are not designed to process efficiently this tremendous amount of information. In this paper all the simulations were carried out using a PC computer having Intel Core i7 CPU 975 processor operating at 3.33 GHz and installed RAM memory of 24 GB.

VII. Conclusions

This paper has presented the experiences, challenges and lessons learned when developing data translators intended for interfacing power-flow programs with EMTP-type programs. The work reported in this paper corresponds to one-way data conversion from several power-flow platforms to EMTP-RV and ATP/EMTP. Several examples are presented to show the implemented solutions.

It has been found that the greatest challenges to overcome when converting steady state data into transient data include: 1) the lack in the source databases of important pieces of information necessary to perform transient studies; 2) the inconsistency and variability in the format of the source data files; 3) the presence of data entry mistakes in very large databases; 4) the validation of the translated data; and 5) the analysis of the large amount of data that transient simulations provide.

To help future developers of interfacing tools, we can list the following recommendations based on experience: 1) before undertaking the translation task, it is recommended to make a complete inventory of the required data, and 2) avoid modifying the source databases as much as possible; in the long run, it is more efficient (with fewer human errors) to write translating code than modifying entries in large files; 3) develop validating software tools to ensure that data are consistent and complete; 4) develop software tools for the analysis of the results when translating large power-flow cases.

The biggest efforts and longest developing times go into the assembly and validation of a complete set of reliable data. Therefore, the more sophisticated the developed tools for data validation, the more efficient the overall translation process will become.

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