Comparison of Simulation Tools ATP-EMTP and MATLAB-Simulink for Time Domain Power System Transient Studies

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Abstract: *Continuous development of appropriate software packages makes simulation of power engineering problems more and more effective. However, these analysis tools differ from each other considerably from the point of view of the applicability to a special problem. The authors compare two widespread environments: MATLAB-SIMULINK, which can be used to simulate a wide spectrum of dynamic systems, and ATP-EMTP, which is specific software to simulate power system transient problems. In the first part of the paper the components (function-blocks) that can be used to build a circuit, are listed. Then three examples are presented which demonstrate the capabilities and underline the advantages and drawbacks of both programs.*

Keywords: *ATP-EMTP, MATLAB-Simulink, time domain simulation, educational use*

1. INTRODUCTION

There are numerous widespread commercial software tools used by power engineers for electrical circuit simulation purposes. It is, however, a challenging and time consuming task to get acquainted with all the details and specialities of such a program, that's why the majority of the users is not inclined to keep tabs on the evolution of similar products or does not even know them.

This paper aims to compare the capabilities of two of such software packages: ATPEMTP/ ATPDRAW and MATLAB-SIMULINK.

The first one is a universal program system for digital simulation of transient phenomena of electromagnetic as well as electromechanical nature, whereas SIMULINK was created to model general dynamic systems using MATLAB simulation engine.the controller designed for the original process is no longer able to achieve the expected system performance.

2. COMPARISON OF THE ELEMENTS OF THE TWO PROGRAMS

Both programs are block-oriented simulators with a graphical user interface. In both cases there are two types of connections between the blocks: electrical and signal wires. Former ones link blocks like transformers, lines etc.

while the latter ones connect the signal processing units. In ATP-EMTP these blocks can be TACS or MODELS objects. The following tables summarise the most important built-in elements (blocks) of the two program packages.

Only objects supported by ATPDraw have been considered in the ATPEMTP column of the next tables. Sources driven by arbitrary signals can be realised in both programs.

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2.1. Sources

ATP	EMTP MATLAB
# DC source, current or voltage, # AC source, current or voltage, # Ungrounded AC or DC voltage source, # AC source, 3 phase, current or voltage, # Ramp source, current or voltage, # Two-slope ramp source, current or voltage, # Double exponential source, # Heidler, Standler, Cigré type source, current or voltage, # TACS controlled source, current or voltage.	# DC voltage source, # AC voltage or current source, External controlled voltage or current source (controlled by an arbitrary signal), # 3-phase programmable control source (time variation of amplitude, phase and frequency by step, ramp or modulation, harmonics in addition

2.2. Switches

ATP	EMTP MATLAB
# Synchronous, 3 phase, # Synchronous with TACS control, 3phase, # Synchronous, set initialisation under ATP, 3 phase #Induction (Asynchronous), set initialisation under ATP, 3 phase, #Induction (Asynchronous), set initialisation under ATP, 1 phase, # DC, set initialisation under ATP	# Synchronous, 3 phase (Fundamental or standard parameters, former ones in SI or pu), # Simplified synchronous, # Permanent magnet synchronous, # Synchronous machine voltage regulator and exciter, # Asynchronous, # DC, # Steam turbine and governor, # Hydraulic turbine and governor.

Both software include the models of the basic electrical rotating machines with the possibility of the correct parameter setting. MATLAB does not contain 1 phase asynchronous machine, but it also includes steam/hydraulic turbine models and permanent magnet synchronous machines. ATP-EMTP comprises a synchronous 3-phase machine, where the field voltage and the mechanical power can be controlled externally (by TACS).

2.3. Lines, Cables

ATP	EMTP MATLAB
Lumped # RLC equivalent 1, 2, 3 phase, # RL coupled non-symmetric 2, 3, 2x3 phase, # RL coupled, symmetric 3, 2x3 phase. **Distributed** # Transposed 1, 2, 3, 6, 2x3, 9 phase, # Untransposed 2, 3 phase. **LCC line/cable** # defined by the geometrical and material data of the line/cable 1…9 phase. Bergeron, Π, J-Marti, Noda and Semlyen type of transmission line models.	**Lumped** #Π Section line, parameters: Number of Π sections and R, L, C values. **Distributed** (based on Bergeron's method) # parameters given by N*N matrices, # parameters given by sequential components.

ATP-EMTP is more suitable for real and idealised simulation of the transmission lines. The most useful type is the LCC model where the geometrical and material data of the line/cable has to be

given only. Skin effect, bundling and transposition can automatically be taken into consideration. No such line/cable model exists in Simulink.

2.4. Transformers

ATP	EMTP MATLAB
# Ideal, 1 phase (only the turn ratio can be given), # Ideal, 3 phase (only the turn ratio can be given), # Saturable, 1 phase (2 windings), # Saturable, 3 phase (2 or 3 windings, the winding connection and phase shift can be chosen), # Saturable, 3 phase, 3-leg core type (Y/Y only) with high homopolar reluctance # BCTRAN	# Linear, 1 phase (2 or 3 windings), # Linear, 3 phase (YgY, YgD1, YgD11, D1Yg, D11Yg, YgYD, YgYgD), # Saturable, 1 phase (2 or 3 windings), # Saturable, 3 phase (YgYgD), # 12 terminal linear 3 phase transformer (the connections can be set manually) Three phase transformers are assembled from single-phase ones.

The transformers are defined by the parameters of the magnetising branch, the voltage, the resistance and the inductance of the windings. The non-linear characteristic of the magnetising branch of a saturable transformer can be given with point-pairs manually or read from a file. MATLAB can not handle the flux linkage between legs.

2.5. Linear Elements

ATP	EMTP MATLAB
# Resistor, # Capacitor with damping resistor, # Inductor with damping resistor, # RLC in series, 1 phase, # RLC in series, 3 phase, # RLC branch 3 phase Y-connected, # RLC branch 3 phase Δ-connected, # Capacitor with initial voltage, # Inductor with initial current.	# Series RLC branch, 1 phase, # Series RLC branch, 3 phase, # Parallel RLC branch, 1 phase, # Parallel RLC branch, 3 phase. Parameters can be defined either as R,L,C or as P and Q. # 3 phase mutual inductance

In this group of simulation elements the two programs are nearly equal. ATP-EMTP has two additional elements: the capacitor/inductor with initial voltage/current. MATLAB can also handle initial conditions, but these can be defined a bit more circuitously.

3. COMPARISON OF SOLUTION METHODS

ATP-EMTP uses fixed time step trapezoidal rule method for solving differential equations, while in Simulink six types of fixed-step and eight types of variable-step solvers can be used, depending on the complexity of the problem.

4. AN EXAMPLE FOR USING ATP-EMTP: SOPHISTICATED TRANSMISSION LINE MODELING

Topic: Comparison of the insulator strings voltage stress of a Hungarian and a Japanese overhead line due to direct lightning flashes into the towers.

In order to perform this task three main steps are necessary:

➢ Creating an equivalent circuit of the transmission line tower including its grounding,

➢ Building a simulation model of the analysed and the neighbouring towers including the transmission line conductors,

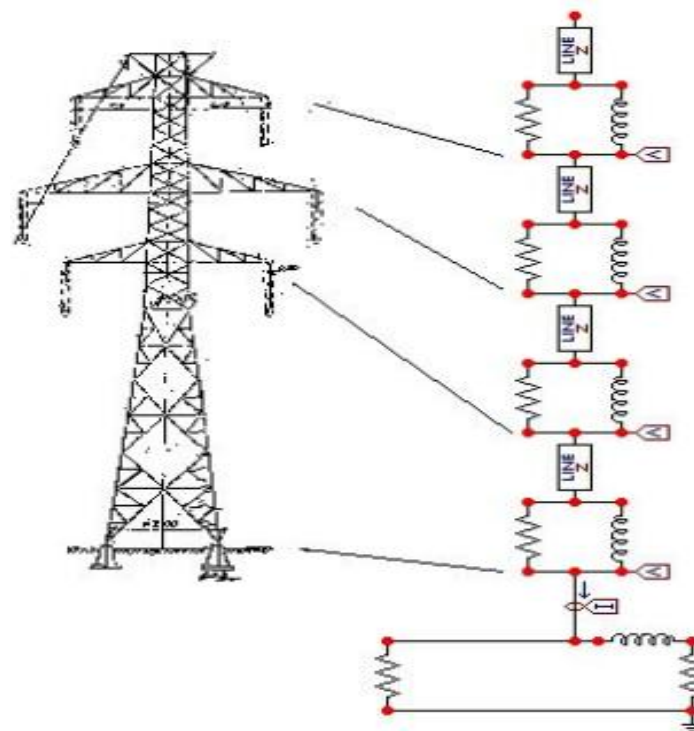➢ Simulation of the wave processes initiated by lightning flashes using ATP-EMTP program.

The analysed towers are plotted in Fig 1.

Fig1. *The analyzed towers*

The equivalent circuits of the towers are determined on the basis of Japanese papers. These papers have replaced the towers by a cylinder to calculate the tower surge impedance because the authors have achieved good arrangement between simulations and field measurements. Table 1. presents the parameters of the equivalent circuits of the analysed towers.

Fig2. *Equivalent circuit of the tower*

Table1. *The equivalent circuit and its parameters of the towers*

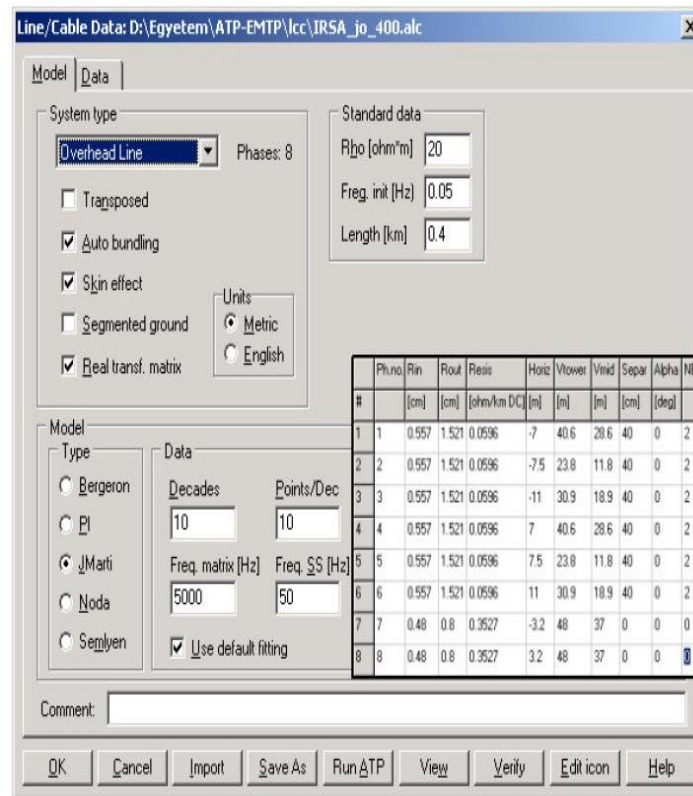|	Hungarian H=49.9 m	Japanese H=120.5 m
Z [Ohm]	132.96	124.22
H1 [m]	4.50	12.50
R1[Ohm]	10.02	10.55
L1 [microH]	3.33	8.47
Z [Ohm]	132.96	124.22
H2 [m]	9.70	20.00
R2 [Ohm]	21.60	16.88
L2 [microH]	7.18	13.56
Z [Ohm]	132.96	124.22
H3 [m]	7.10	20.00
R3 [Ohm]	15.81	16.88
L3 [microH]	5.26	13.56
Z [Ohm]	132.96	124.22
H4 [m]	28.60	68.00
R4 [Ohm]	47.42	44.31
L4 [microH]	15.78	35.59
Grounding	R1=50 Ohm	R2=20 Ohm L2=5 microH

Fig3. *The parameters of the transmission line between the towers.*

On the basis of the travelling wave phenomenon the neighbouring towers had to be simulated correctly because these elements have a significant effect during lightning. The transmission lines between the towers are defined by the electrical and geometrical parameters of the conductors (phase conductors and shield wire). The phase conductors are bundled. J-Marti transmission line model is used during simulations in the frequency range of 5x10-2 Hz - 5x108 Hz, taking into account the skin effect. Fig 2. shows the parameters of the Hungarian transmission line.

The lightning flash is substituted by a HEIDLER-type surge current generator and a resistor (Norton generator). Fig 3. shows the voltage stress of the insulator strings in each phase for one current (lightning) flash. The effect of the reflected waves can be analysed on the basis of the voltage curves. The main reflection points are the grounding (0.34 □ s = 2x0.17 □ s = 2xtravelling time of a Hungarian tower [50m]) and the neighbouring towers (2.66 □ s = 2x1.33 □ s = 2x travelling time of the span between the towers [400m]).
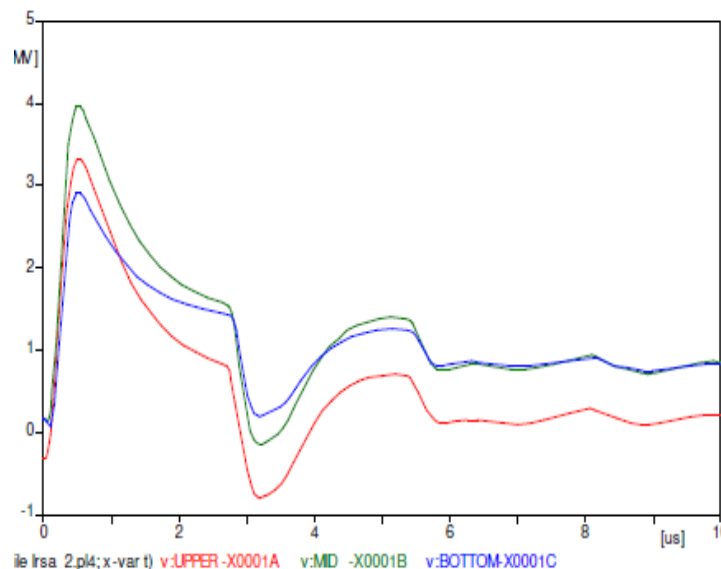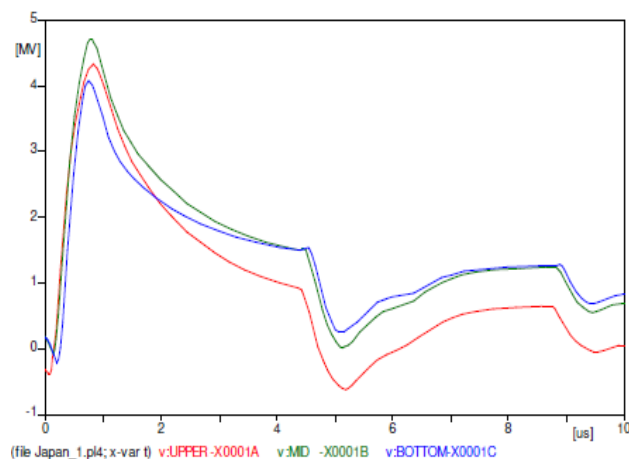
Fig4. *The voltage stress of the insulator strings in each phase*

5. CONCLUSIONS

In the paper two widely used program packages for electric network simulation were compared. It has to be pointed out that both tools are capable of simulating the same class of problems, since it is possible to build user defined elements in both cases (though this requires experience and is time-consuming). There are however some differences between the predefined components. ATP-EMTP is designed to simulate the physical processes of transmission lines and transformers quickly and in a convenient way but MATLAB offers more possibilities in power electronics, signal processing and control. The paper also shows three examples that demonstrate the mainstays of the surveyed software tools.

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