Utilising of EMTP ATP for Modelling of Decentralized Power Sources Connection

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Abstract—**The ensuring of the quality of electric power is one of the actual tasks that could be solved in the field of electric power supplying. For that reason it is necessary to monitor the particular electric quantities, such as voltage and current fluctuations, overvoltages, voltage drops, voltage harmonic distortion, asymmetry phase voltages, frequency variation and fluctuation and others that cause e.g. power losses, devices failure, and so on.**

This article deals with some typical failures in a power system that unfavourably cause considerable electric losses or undesirable damages. The prevention of potential failure leads to decreasing of power losses. It is possible to solve the various power networks using computer modelling. One of the suitable computer software is the Electromagnetic Transient Program (EMTP ATP). This software is mostly intended for solving and modelling transient phenomena and this feature was also utilized during the modelling. In this software there were modelled various connections of decentralized power sources and determined the maximum power and node voltage that can be connected in particular part of the power grid. In this article there are also indicated another various failures that caused significant power losses (short-circuits, overvoltages caused by connection and disconnection of a part of the grid, atmospheric overvoltages).

Keywords—power system, computer modelling, EMTP ATP, decentralized sources, SimPowerSystem, electric losses.

I. Introduction

A. Reconnection problems of decentralized power energy sources to distribution grid

Reconnection problems of wind power plant:

- convention sources must be „on“ and prepared, in the case of wind power plants outage;
- dependence on actual meteorological situation;
- relatively small power of wind power plants;
- they are not possible to operate when the wind velocity is above 30 $m \cdot s^{-1}$ or below 3 $m \cdot s^{-1}$.

Reconnection problems of solar power plants:

- convention sources must be „on“ and prepared, in the case of solar power plants outage;
- problems with the season variations of sunlight (in December is 7-times weaker than in July);
- difference between night and day is very significant.

Reconnection problems of water power plants:

- they generate electric power only when the water flows is in allowable range.

B. EMTP ATP (Electromagnetic Transient Program)

- Generally, there is possible to model the power system network of 250 nodes, 300 linear branches, 40 switchers, 50 sources, ...
- Circuits can be assembled from various electric component of the power system:
  - Components with the lumped parameters *R*, *L*, *C*;
  - Components with the mutual coupling (transformers, overhead lines, ...);
  - Multiphase transmission lines with lumped or distributed parameters, that can be frequency-dependent;
  - Nonlinear components *R*, *L*, *C*;
  - Switchers with variable switching conditions, that are determined for simulation of protection relays, spark gaps, diodes, thyristors and other changes of the net connection;
  - Voltage and current sources of various frequencies. Besides of standard mathematical functions, there is possible to define also sources as a function of time;
  - Model of three-phase synchronous machine with rotor, exciting winding, damping winding;
  - Models of universal motor for simulation of three-phase induction motor, one-phase alternating motor and direct current motor;
  - Components of controlling system and sense points.

II. Choosing of Suitable Model of Power System for Connection of Decentralized Sources

There was chosen a part of the radial network on the eastern side of Slovakia for choosing a suitable model of the power system for determination of electric losses of the connected decentralized sources. The power system is on 22 kV voltage level and it is supplied from 110 kV lines through the transformer. The chosen network with particular parameters of components was modelled in program EMTP ATP.

Parameters of power system

The input parameters of particular devices were entered according to obtained data (length, diameter, material of overhead lines, transformers parameters, and so on). Individual loads were set in respect of relevant actual connected appliances.

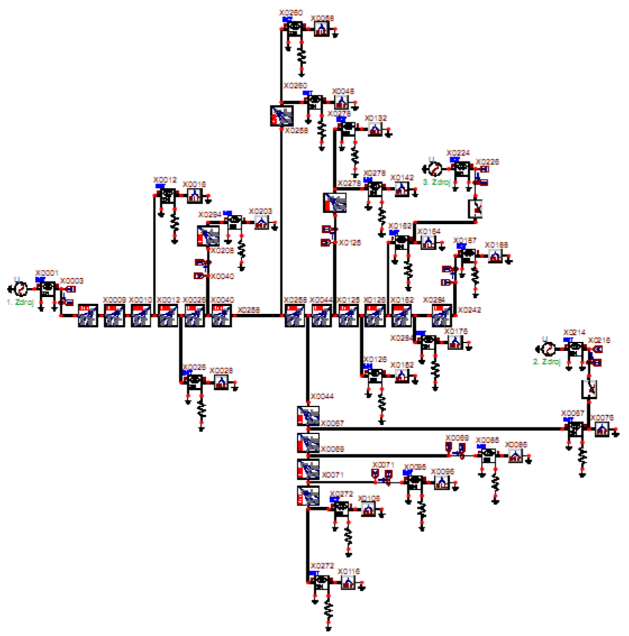


Fig. 1. Schema of electric power network for simulations in EMTP-ATP

A. Reconnection of power sources

- There were reconnected various sources in different locations of the power system
- The first source was connected from the beginning of the simulation, the second one was connected at 0,5 s and the third one at 1 s
- All parameters of components in the power system were inserted as the card data of given components
- Consequently, there were changed voltages and powers of the connected sources
- The measured data (voltages, currents, ...) were recorded and evaluated in various nodes of the network
- The maximum possible connected power was calculated and tested with permitted difference of voltages (quality of voltages must agree with conditions of ± 2 % from the nominal voltage in grid) (see conditions in ref. [5])
- The results were evaluated for the phase L1 (A), because the loads were almost symmetrical

TABLE I.
SIMULATION OF RECONNECTION OF TWO SOURCES WITH THE VARIOUS PARAMETERS AND THE MAXIMUM VOLTAGE OF 391 V (2ND SOURCE) AND 333 V (3RD SOURCE)

	node	node	node	node	Node	node	node	Node
VN	X0003	X0040	X0125	X0069	X0071	X0067	X0162	
1 [V]	17933	17815	17723	17709	17703	17744	17710	
1+2 [V]	18090	18105	18089	18094	18088	18129	18075	
1+2+3[V]	18092	18115	18111	18110	18104	18145	18102	
NN	X0016	X0058	X0132	X0164	X0188	X0076	X0096	X0116
1 [V]	319,48	317,91	317,95	317,75	318,51	322,7	318,81	318,49
1+2 [V]	322,9	323,98	324,55	324,35	325,13	**332,85**	325,78	325,45
1+2+3[V]	322,96	324,23	324,92	**332,04**	325,58	**333,12**	326,05	325,71

Maximum voltages, that are possible to reach with the respecting of ± 2 % voltage variation in every node:

- Source 1: U_{m1} = 89815 V
- Source 2: U_{m2} = 391 V
- Source 3: U_{m3} = 333 V

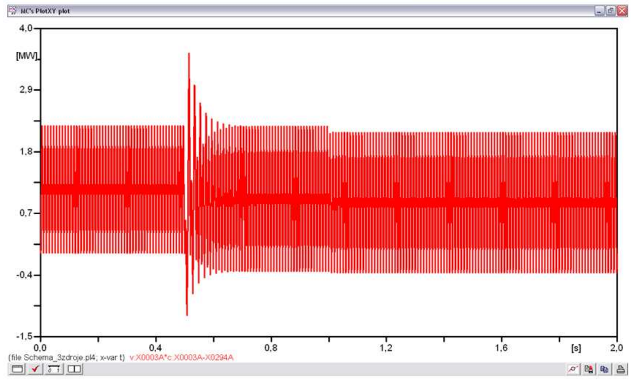


Fig. 2. Power of the first source, when it operates alone (0 ÷ 0,5 s), with the second one (0,5 ÷1 s) and consequently with the third one (1 ÷ 2 s)

The maximum immediate power measured in the closest distances from the sources:

- Power of the source 1 (single) = **2,2643 MW**
- Power of the sources 1 and 2 = **3,5280 MW** = 2,2541 MW + 1,2739 MW
- Power of the sources 1 and 2 and 3 = **3,5653 MW** = 2,1458 MW + 1,2621 MW + 0,1574 MW

III. TRANSIENT SIMULATIONS OF CHOSEN ELECTRIC SOURCES IN THE POWER SYSTEM MODEL IN EMTP-ATP

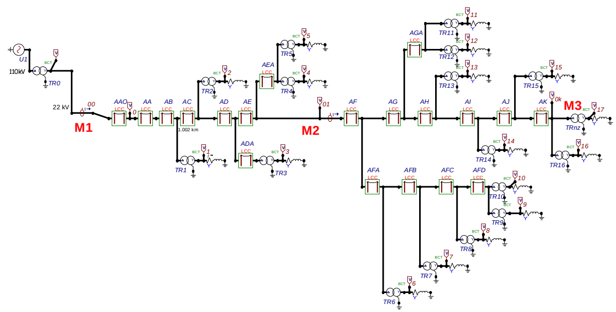


Fig. 3. Complemented schema (in EMTP-ATP version 5) for the simulation of transient phenomena in M1, M2, M3 – places of failure event; measuring places

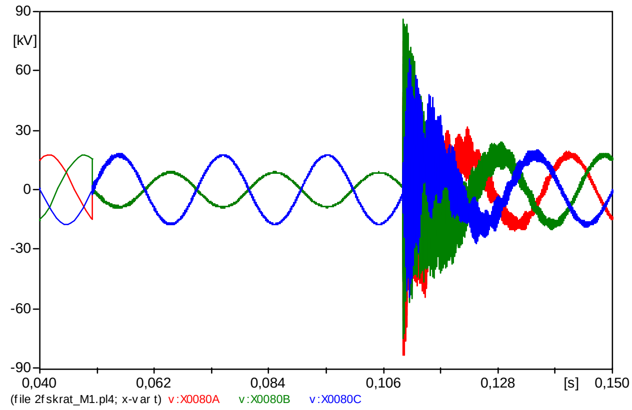


Fig. 4. Voltage characteristics before two-phase short-circuit (overvoltage after short circuit elimination) in location M1, during the short circuit and after short circuit, measured in location M1 (see Fig. 3)

TABLE II.
TWO-PHASE SHORT CIRCUIT – MEASURED RESULTS

Measured place	Location M1	Steady state	Overvoltage after short-circuit interruption	Peak current during short-circuit
	Mutual distances [km]	*U* [V]	*U* [V]	i_p [A]
M1	0	17309	86268	3122,3
M2	4,110	16969	71133	197,08
M3	8,121	16701	69032	36,822

Measured place	Location M1	Steady state	Overvoltage after short-circuit interruption	Peak current during short-circuit
	Mutual distances [km]	*U* [V]	*U* [V]	i_p [A]
M1	– 4,110	17309	167630	2536,6
M2	0	16969	178690	2697,5
M3	4,011	16701	163660	36,975

Measured place	Location M1	Steady state	Overvoltage after short-circuit interruption	Peak current during short-circuit
	Mutual distances [km]	*U* [V]	*U* [V]	i_p [A]
M1	7,466	17309	69409	1881,2
M2	4,011	16969	67746	1854
M3	0	16701	98249	1938

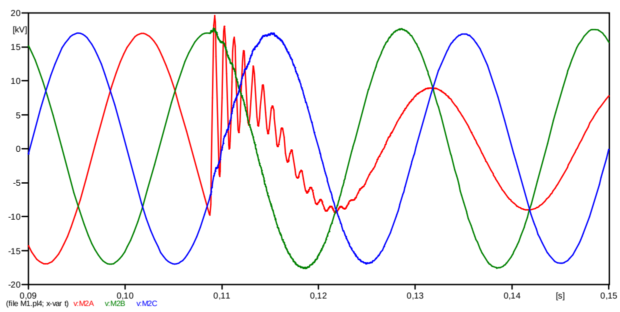


Fig. 5. Voltage characteristics during the phase interruption in location M1, measured in location M2 (see Fig. 3)

IV. COMPARISON OF SIMULATION ALGORITHM TO MATLAB / SIMPOWERSYSTEM

According to the schema in EMTP ATP in Fig. 3 there was created in Matlab/SimPowerSystem the model of the network (Fig 6).

Fig. 6 shows the model of the power system, it is the inefficiently grounded network. In the schema, there are situated particular branches, respectively loads. The presented chosen part of the schema (section) is in the main line AA-AL 8121 m long. The sections have their circuit breakers that are marked S17-S20. These circuit breakers can switch off the whole section in the case of maintenance or revision of this section.

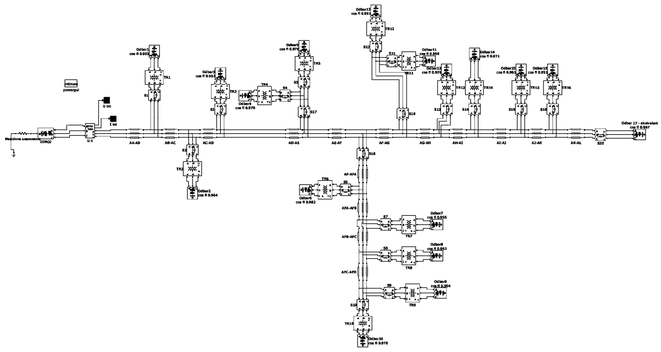


Fig. 6. Model schema of the chosen part of the power system in the Matlab/SimPowerSystems

V. THREE-PHASE SHORT-CIRCUIT ON OVERHEAD LINE

In this type of fault the metal connecting of all three phases occurred. The part of the network is in Fig. 7, where 3-phase short-circuit occurred. In this case, the load no. 17 was disconnected. The three-phase short-circuit occurred before the switcher no. 8 at the time of t_1 = 0,04 s and the failure was removed at the time of t_2 = 0,1 s.

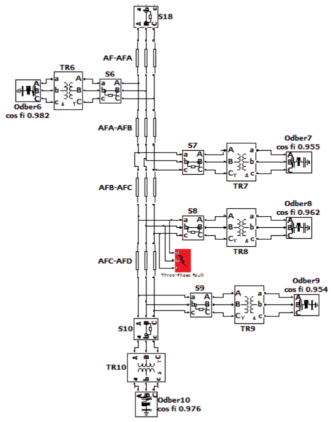
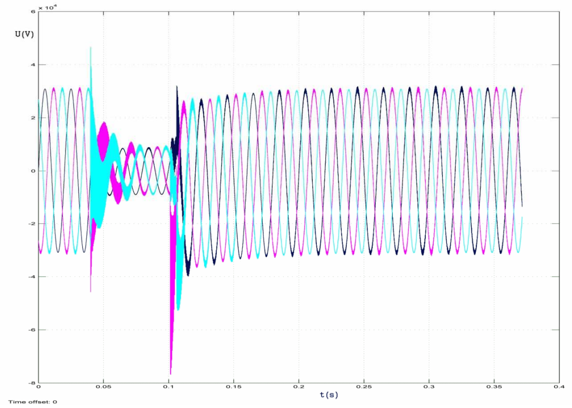


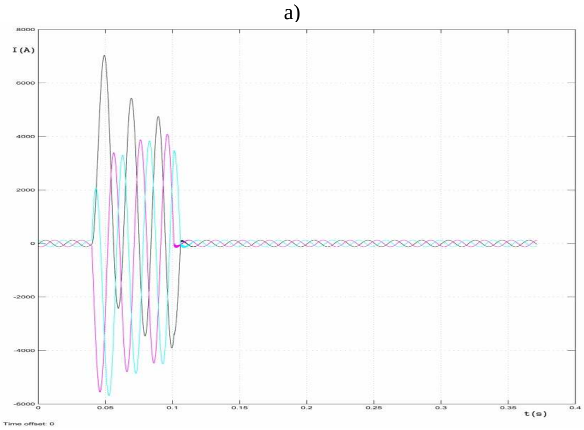
Fig. 7. Part of the power network with the highlighting of the fault place (three-phase short-circuit)

As one can see from the resulting characteristics in Fig. 8a, there occurred the overvoltage in all three phases. After short-circuit creation, in the phase L3, one can read at the time t_{k1} = 0,0401 s the magnitude of the overvoltage at the level $U_{3k,max}$ = 32996 V. After removing the failure (at the time of 0,1 s) then occurs to consequential overvoltage rising with the highest magnitude in phase L2 at the level $U_{2K,max}$ = 54327 V (at the time of t_{k2} = 0,1017 s), in the negative half period. To eliminate the overvoltages and shock currents (impulse character) it is recommended, as in this case, to use surge overvoltages.

During the short-circuit, there can be observed the rapid current rising from the value I = 89,02 A to value of peak short-circuit current in the phase L3, i_{p3} = 4977 A (at the time of t_1 = 0,049 s) (Fig. 8b). These impulse values of current can be very dangerous for the equipment in the network. For dimensioning of equipment and setting of overcurrent protections it is necessary to ensure the correct setting of the particular protection. After incorrect setting of the protection there can occur dynamic and thermal effects of short-circuit, that can damage the equipment.



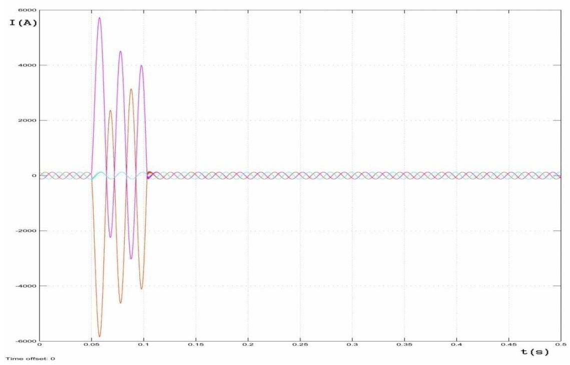
a)



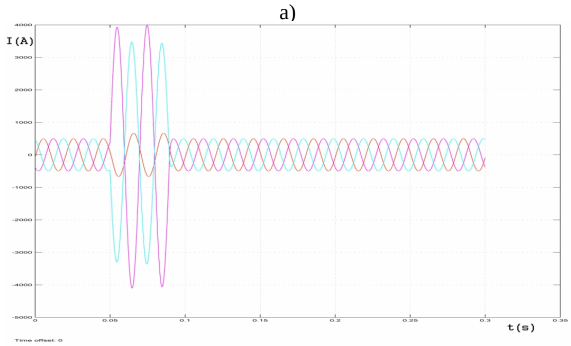
b)

Fig. 8. Voltage (a) and current (b) characteristics in 3-phase short-circuit

A similar procedure can be applied to other types of faults as it is shown in Fig. 9.



a)



b)

Fig. 9. Characteristics of the current in 2-phase metal short-circuit (a) and 2-phase earth-fault (b)

VI. CONCLUSION

- By use of the EMTP-ATP and SimPowerSystem it is possible relatively quickly consider the connectivity of new power source (voltage change, short-circuit ratio, overvoltage, ...) and determine the power losses on particular devices;
- there were confirmed the theoretical assumptions that the most important points with the highest quantity change are the closest branches to investigated node, i.e.:
  - the highest increase of the voltage magnitude is in the node, where the new source is connected,
  - the highest increase of the short-circuit current is also in the node of the source connection,
- if there were connected 3 sources, the voltage in the power system was increased to permitted maximum voltage, and then it is possible to connect another load to the grid without significant complications,
- a similar procedure can be used for various small power systems.

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REFERENCES

[1] Medveď, D.: *Electric losses modeling of decentralized power sources connection using EMTP ATP*. In: ELEN 2010, ČVUT Praha, 2010, p. 1-9. ISBN 978-80-254-8089-2.

[2] Medveď, D., Nemergut, L.: *Modelovanie prechodných javov využitím nástroja MatlabSimPowerSystem*. In: Electrical Engineering and Informatics 3: proceeding of the Faculty of Electrical Engineering and Informatics of the Technical University of Košice. Košice: FEI TU, 2012 s. 745-748. ISBN 978-80-553-0890-6.

[3] Szathmáry, P., Kanálik, M., Rusnák, J., Hvizdoš, M.: *Nepriaznivé vplyvy nesymetrie napätia na elektrické zariadenia a možnosti ich eliminácie.* In: AT&P journal. č. 2 (2010), s. 51-53. ISSN 1336-233X.

[4] Kolcun, M.: *Electric power system operation control*. In: Efektywność w sektorze dystrybucji energii elektrycznej: aspekty techniczne. - Bydgoszcz: Wydawnictwo Tekst, 2009. pp. 113-134. ISBN 978-83-7208-022-6.

[5] Východoslovenská distribučná a.s.: *Pripojenie energetického zariadenia na výrobu elektriny do distribučnej sústavy* [online]. [cit 2012-12-12]. Dostupné na internete: < http://www.vsds.sk/wps/portal/vsd/domov/vyrobcovia/pripojenie-zdroja >.

[6] Medveď, D., Hvizdoš, M.: *Modelovanie v prostredí EMTP – ATP*. 1. vyd. Košice: TU 2011. 74 s. ISBN 978-80-553-0776-3.

[7] Medveď, D.: *Modelovanie prechodných dejov pri pripojovaní rozptýlených zdrojov energie v prostredí EMTP ATP*. In: Elektroenergetika, Vol. 3, No. 7, 2010, p. 15-18. ISSN 1337-6756.

[8] Hvizdoš, M.: *Modelovanie prevádzkových a poruchových stavov v elektrizačnej sústave*. In: E2006/10 – Simulace a dynamické modelování systémů a procesů v elektrizační soustavě, EGÚ Praha, 2006, p. 1-16.

[9] Medveď, D.: *Modelovanie v elektroenergetike – Zbierka príkladov 1*. [1. vyd.] - Košice : TU, 2012. 204 s. ISBN 978-80-553-1188-3.