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Analysis of Voltage and Current Conditions at High Voltage Electric Network, Measuring of Surface Voltage Gradient and Touch Voltage

Karel Sokanský, Stanislav Mišák

Faculty of Electrical Engineering and Informatics, Technical University Ostrava, Czech Republic

Abstract – A determination of voltage and current conditions were needful for increasing reliability and for reduction of a number of faults in the high voltage electric network. Increasing effectiveness and selectivity of readjusting relay protections evaluated faults, easier dimensioning of devices in the high voltage electric network and so on is possible by virtue of results from this analysis. The analysis of faults, including diagnostic of electric network devices, forms basis for reliability working of electric network and basis for design of protection systems.

Keywords: High Voltage Electric Network, Fault states, Measuring of Surface Voltage Gradient and Touch Voltage

1. INTRODUCTION

The determination of voltage and current conditions for different types of running and faults the states are basis for operation of any electric network. Increasing accurately adjusting of relay protections is possible on the basis of this analysis. And then, these relay protections switch within short time interval and with requested selectivity. In cooperation with SME Company (one of the major provider of electric energy in the Czech Republic) was made several experiments in 2003 and 2004 [1]. Earth-faults in the high voltage (22 kV) electric networks indirectly grounded by Petersen grounding coil were mostly simulated. The brief description of the last measuring at 22 kV switching station Frýdlant is introduced within this paper.

Fig. 1 Switching station 22 kV Frýdlant

The determination voltage and current conditions were made for case of iron ground connection and high-ohm earth-fault in this measuring. Starting elements of relay protections were readjusted on the basis of these results. At the concrete, current by earth fault and current in the node of transformer was measured for all above mentioned types of earth-faults. And next, there were measured surface voltage gradient and touch voltage in the place of earth-fault. Before realization of the experiment, assumed values of currents and voltages for individual types of earth faults were determined with using program EMTP-ATP. And last but not least, part of experiment was applied to verification of the possibility of using method localization of ground connections by external signal.

2. REALIZATION OF EXPERIMENT

Measuring of voltage and current conditions for all above mentioned types of earth-fault was realized at two measuring stations. The course of current by earth fault, surface voltage gradient and touch voltage were measured in the first measuring place (at place of earth-fault).

The surface voltage gradient and touch voltage were measured with using voltage ratio boxes. Output signals of individual voltage ratio boxes were processed by oscilloscope Yokogawa (16 bits, 8 channels). The course of current through place of ground connection was measured by current transformer and evaluated by oscilloscope Yokogawa too. The measuring apparatus, in case of measuring of current by earth-fault and surface voltage gradient, is shown in Fig. 2. The current by transformer was measured at second measuring station, in switching station 22 kV Frýdlant.

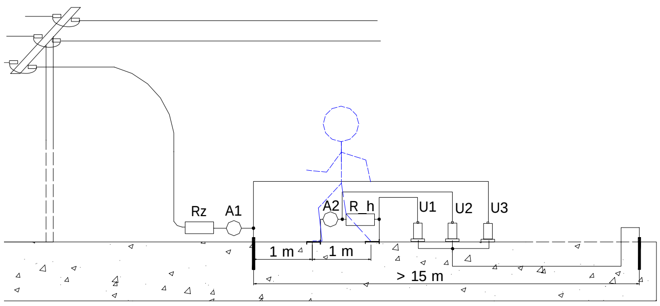

Fig. 2 Measuring of current by earth-fault and surface voltage gradient

Apparently from Fig. 2, the measuring was realized for case of downfallen conductor, where resistor R_z defines resistance of earth-fault (see Fig. 3). At the same time, measuring was realized for tuned inductor (capacitive component of current was compensated). Therefore, value of surface voltage gradient was determined for influence of residual current. The value of surface voltage gradient was specified according to trivial equation

$$U_{\text{step}} = U_2 - U_1 \cong I_2 \cdot R_{\_\text{h}} \qquad (1)$$

Because surface voltage gradient was measured at the moment of earth-fault inception, there was not respected impedance of human's derma. There was respected only inner impedance of human and this impedance has mainly resistance character ($R_{\_\text{h}}$).

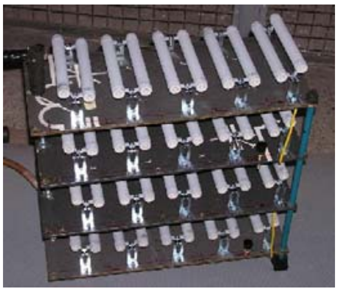

Fig. 3 Segmented resistor defining resistance of earth-fault

Measuring of surface voltage gradient was made for three values resistance of human body (1; 1,5 and 3 kΩ) and current's course foot-foot.

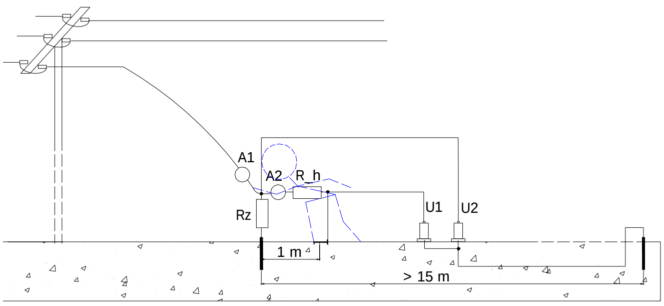

Fig. 4 Measuring of current by earth-fault and touch voltage

Touch voltage was measured according to trivial equation (current's course hand-body-foot):

$$U_{\text{touch}} = U_2 - U_1 \cong I_2 \cdot R_{\_\text{h}} \qquad (2)$$

And measuring apparatus are shown in Fig. 4. These measuring methods (for measuring of touch and surface gradient voltage) are not so typical, that is why to keep the terms of safeness is necessary. On the other side, the results from these simulations are very accurate and authentic. In case of measuring the touch voltage and surface voltage gradient near switching station, where the measuring can be influenced by nominal frequency and harmonic frequency, it is necessary to use current's source with different frequency then nominal. Then, touch voltage and surface voltage gradient are measured by selective voltmeter. The principal scheme of this system is shown in Fig. 4.

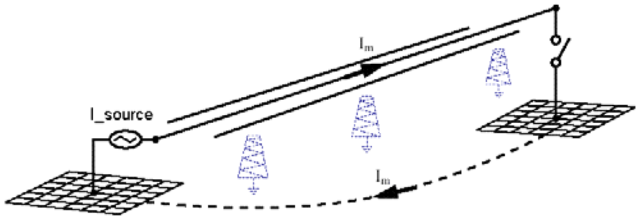

Fig. 4 Principal scheme of measuring system with separate current's source and selective voltmeter

2.1 current and voltages courses for individual types of earth faults

Simulation of iron earth-fault was realized at first. A ground electrode of 22 kV tower was used as earth potential.

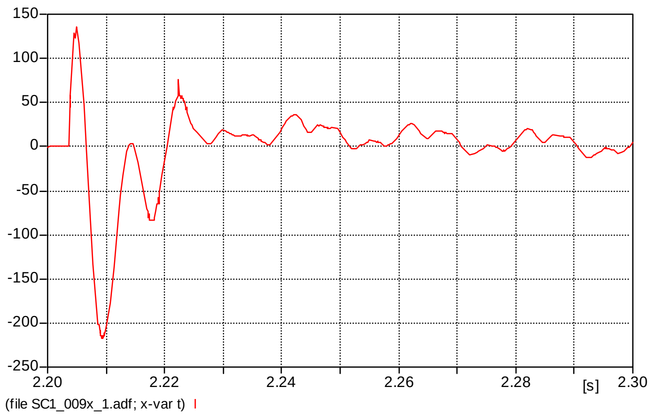

Fig.5 Course of current by iron earth-fault (detail of current's stroke)

For example, the course of current by iron earth-fault (detail of current's stroke) in unit of amperes is shown in Fig. 5. ($R_{\_\text{h}}$ = 1,5 kΩ).

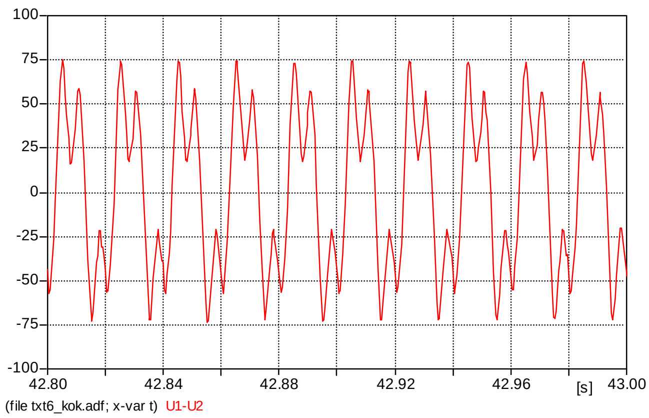

Fig.6 Course of touch voltage for iron earth-fault (detail of steady-state)

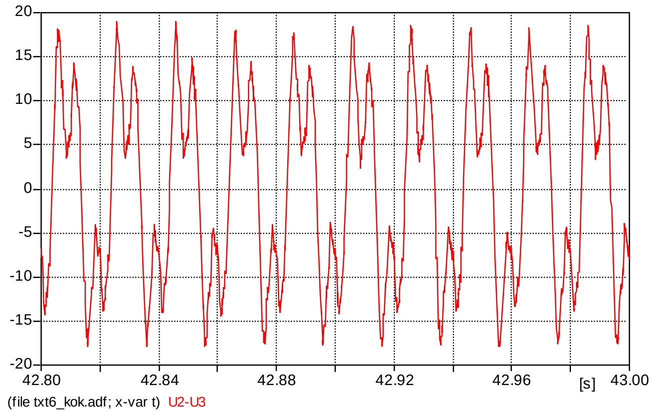

Fig.7 Course of surface voltage gradient for iron earth-fault (detail of steady-state)

The courses of touch voltage and surface voltage gradient are shown for iron earth-fault and resistance of human body 1,5 kΩ in Fig. 6 and 7.

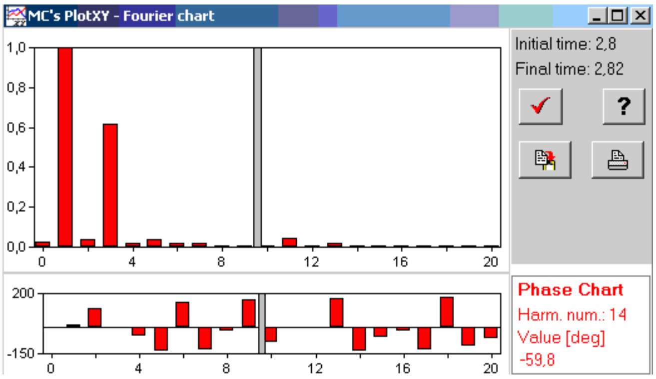

Fig. 8 FFT analysis of current by earth fault (steady-state)

And next, simulations of high-ohm earth-faults were executed as a second. The resistance of earth-fault was respected by designated segmental resistor. This segmental resistor make possible of definitions ground resistance with values 1600, 800 and 400 Ω.

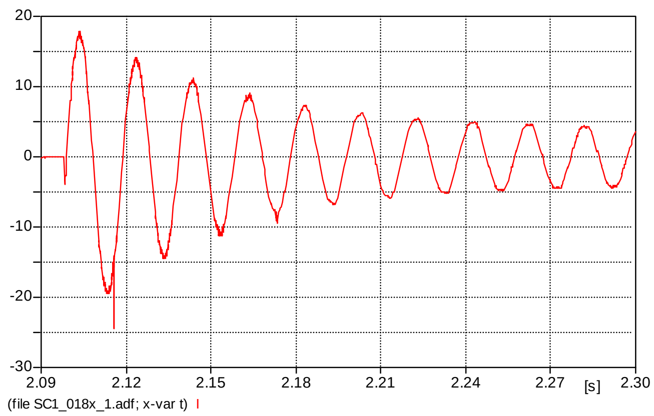

Fig. 9 Course of current by 800 Ω earth-fault (detail of current's stroke)

For compare, course of current by 800 Ω earth-fault (detail of current's stroke) is shown in Fig. 9.
Final results, from measuring of mentioned types of earth-faults, are shown in the TABLE I.

TABLE I Final results from measuring of earth faults

Types of earth-faults	Current of earth-fault			U_{touch}		U_{step}	
	I_m'' (A)	I_{steady} (A)	I_{rms} (A)	max (V)	RMS (V)	max (V)	RMS (V)
Iron	217,6	15,6	7,47	74,0	38,4	9	4,03
High-ohms 400 Ω	32,7	4,31	3,06	1176	840	11,6	5,71
High-ohms 800 Ω	19,4	3,97	2,84	2178	1560	26,6	15,1
High-ohms 1600 Ω	15,0	3,61	2,57	2201	1604	31,4	18,2
Down-fallen cond.	Ind.	4,93	3,05	591	388	11,5	6,48

Where I_m'' is surge current (A), I_{steady} is value of earth-fault current in steady-state (A), I_{rms} is effective value of earth-fault current in steady-state (A), U_{touch} is max/RMS maximal/effective value of touch voltage (V) and U_{step} is max/RMS maximal/effective value of surface voltage gradient (V).

3. CONCLUSION

Results from measuring were used for more accurately adjusting of relay protections. It is evident (from TABLE I) that exceeding values 250 V for touch voltages with time period is longer than one second. And it is non-permissible according to norm ČSN 33 200-4-41. Procedure for moderate the health hazard will be proposed. Measuring of surface voltage gradient and touch voltage is recommended in other localities of electric networks of SME Company.

REFERENCES

[1] K. Sokanský, S. Mišák: Ground connections in the 22 kV electric networks. *In: conference Poděbrady 2004*, 2004

AUTHORS

Prof. Ing. Karel Sokanský, CSc., Faculty of Electrical Engineering and Informatics, Technical University Ostrava, 708 33 Ostrava, Czech Republic, Tel.:+420 596995181,
Email: karel.sokansky@vsb.cz.

Ing. Stanislav Mišák, Faculty of Electrical Engineering and Informatics, Technical University Ostrava, 708 33 Ostrava, Czech Republic, Tel.:+420 596993469,
Email: stanislav.misak@vsb.cz.