Electromagnetic Transient Components Induced by Faults in the Different Coupled Transmission Line

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Abstract - Transient analysis of the electromagnetic transient components induced in transmission line systems during system operation or fault conditions is presented in this paper. On the basis of the investigations more conclusions are presented. It is shown that high frequency component can occur on non faulted line in high voltage system, following fault initiation on other lines working on the same tower construction. The high frequency components associated with transmission line faults can not be controlled by any input installation of the transmission line relay and moreover this components can not be used by location of fault. The most attention was dedicated to the results of the interaction between HVDC and AC transmission line situated on the same right-of-way or working on the same tower construction.

Keywords: AC and HVDC transmission line, transients, overvoltages, Netomac

1. INTRODUCTION

In practice construction of the high (HV) and extra high voltage (EHV) transmission lines occurs very often, that two or more lines for some specific section run closer or even work on the same tower construction. In Polish Power System (PPS) is in the next future considering the possibility of the better connection between PPS and UCPTE with the help of the new high voltage direct current (HVDC) transmission line (so-called East-West Power Bridge). In this paper the results of transient analysis during faults in hv and ehv transmission lines working closer or on the same tower construction are presented taking into consideration the HVDC transmission line. The voltage and current are characterized by an initial relatively high-noise period of duration, during which time significant high-frequency oscillations occur. During the faults the high frequency component appear in the same line as well but the overvoltages occur in the non-faulted parallel line. The overvoltages in the sound transmission line are represented as the superposition of the transients produced due the coupling parameters of both lines. These overvoltages can in some cases lead to false operation of the line protection [4]. Because of the impossibility to make the investigation in the real system (in Poland till now the HVDC lines do not exist) there are necessary to use the simulation model and adequate computer program. The computer investigations should give the information about the influence of the interaction transients and as a consequence about the limitation for the operation of the AC and HVDC transmission line on the same tower construction.

II SHORT DESCRIPTION OF USED PROGRAM

It's well know that a single physical component may have different model representations depending upon the context of the problems. Power system networks are subjected to many forms of transient phenomena ranging from the relatively slow electromechanical oscillation associated with synchronous machine instability through electromagnetic transients to the fast variation in voltage and current. In principle the representation of the individual network elements must correspond to the specific frequency range of the particular transient phenomena. As the simulation tools the NETOMAC program [2,3] was used where the different models of system elements can be changed during calculation.

Using such solution all transients in high voltage system can be determine very fast without risk and with very high flexibility. The dynamic calculations can be carried out in original L1, L2, L3 system, and the symmetric system can be determined very easy by the parameter of one phase. The problem with the difficult construction of the input data file can be avoided with the help of the auxiliary program NETCAD. This program enable to introduce the input data in the graphic format.

III. RESULTS OF CALCULATIONS

A. Description of the investigated system

Two cases were taken into consideration (Fig.1): the 500 kV bipolar line without ground wires, which is on the same right-of-way as double system 400 kV transmission line. The line length is 45.9 km. The Marti model [4] was used for both lines and it was assumed that the conductors are the same for the AC . and DC line. The earth is homogeneous with uniform resistivity ρ = 100 Ωm. The transmission lines are represented in detail but remainder of the system is modeled using reduced-order network equivalents without significant loss of accuracy. The full system was reduced to simple structure with the approximation technique which allows the control of the approximation error in any time interval. The principle of this method is the comparison of time-domain results obtained using the full system and equivalent representations

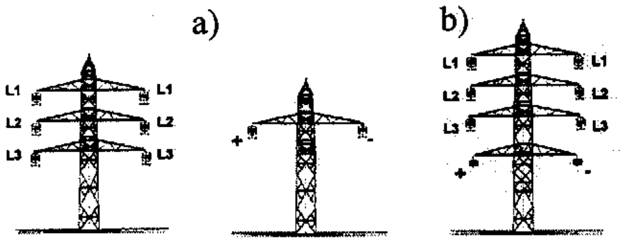

Fig. 1. Configuration of the investigated overhead lines:
a) HVDC line leaded in neighborhood of the AC line
b) HVDC line leaded with AC line on the same tower constructions

B. Description of the results of investigation

This work is concerned with the most severe conditions of fault and shows the possibility of the overvoltages caused by faults in HVDC or AC transmission lines.

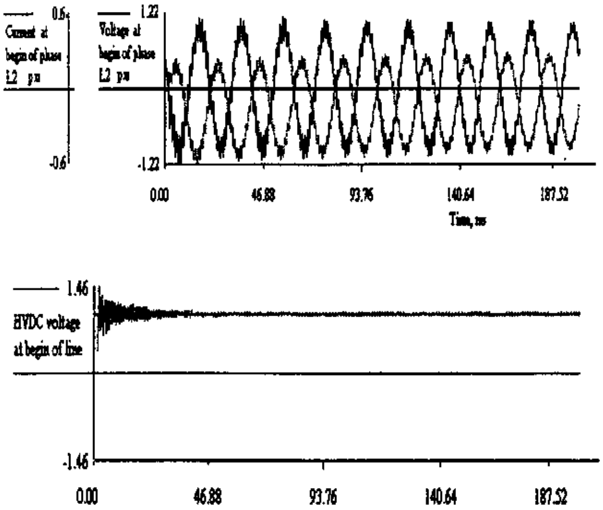

Fig.2. Waveforms of voltage and circuit in phase L2 of AC line and voltage in pole - of HVDC line during the fault in phase L1 at the end of AC line

Because of the line configurations there was taking into account the overvoltages which can cause in faulted and sound phases. All results are presented in p.u. what make easier the obtain the overvoltage factors for any individual case. It was assumed that the faults were simulated at the end of the line but the measurement point was always situated at the beginning of this line. The short-circuit resistance is 1mΩ. Fig. 2 shows the example voltage waveform during the one phase-to-ground fault but the combination of the overvoltage factors are presented in the table 1.

In the Fig.3 the voltage waveform are presented at the beginning of AC and HVDC lines during the two phase fault L1+L2.

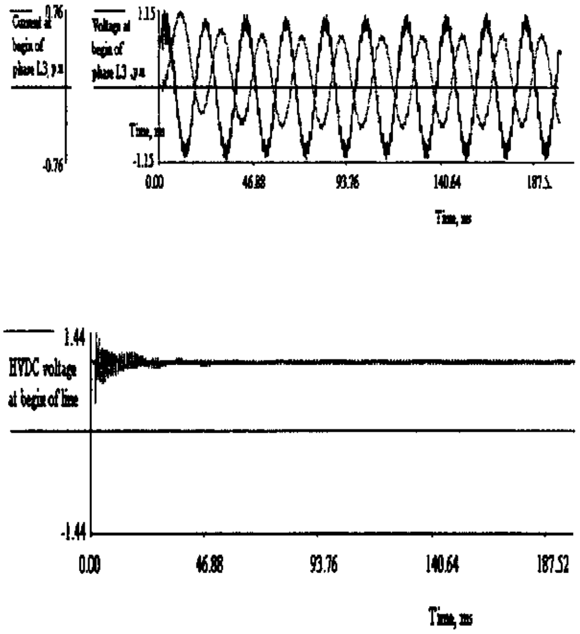

Fig.3. Voltage and current waveforms in phase L3 of AC line and voltage in pole - of HVDC line during the two phase fault between L1 and L2 phases at the end of HVAC line

Fig.4 shows the same waveforms but during three-phase-to-ground fault.

Fig.5 shows the voltage and current waveforms in phase L1 of AC line and the voltage waveform at the beginning of pole + of HVDC line during the monopolar fault at the end of pole + of HVDC line.

Finally in the Fig.6 the voltage and current waveforms in the phase L1 of AC line and voltage waveform in pole + of HVDC line during the bipolar fault on end of the HVDC line are shown.

Table 1. Overvoltage factors in transmission lines with the configuration as shown in Fig.1a) during different faults

Fault	Phase L1 system 1	Phase L2 system 1	Phase L3 system 1	Phase L1 system 2	Phase L2 system 2	Phase L3 system 2	Line HVDC pole+	Line HVDC pole-
L1+Earth	1.00	1.22	1.12	1.00	1.22	1.12	1.41	1.46
L1+L2+Earth	1.00	0.91	1.15	1.00	0.91	1.15	1.39	1.44
L1+L2+L3	1.14	1.02	2.11	1.14	1.02	2.11	1.27	1.46
HVDC+Earth	1.28	1.08	1.04	1.28	1.08	1.04	1.31	1.07
HVDC+ HVDC-	1.37	1.15	1.08	1.37	1.14	1.08	1.82	2.15

Table 2. Overvoltage factors in transmission lines with the configuration as shown in Fig.1b) during different faults

Fault	Phase L1 system 1	Phase L2 system 1	Phase L3 system 1	Phase L1 system 2	Phase L2 system 2	Phase L3 system 2	Line HVDC pole+	Line HVDC pole-
L1+Earth	1.11	1.22	1.13	1.11	1.21	1.13	1.46	1.15
L1+L2+Earth	1.14	0.8	1.34	1.14	0.8	1.34	1.35	1.06
L1+L2+L3	1.65	0.5	2.17	1.66	0.5	2.17	1.17	1.07
HVDC+Earth	1.32	1.1	1.08	1.32	1.1	1.07	1.44	1.36
HVDC+ HVDC-	1.02	1.02	1.02	1.02	1.02	1.02	2.12	2.12

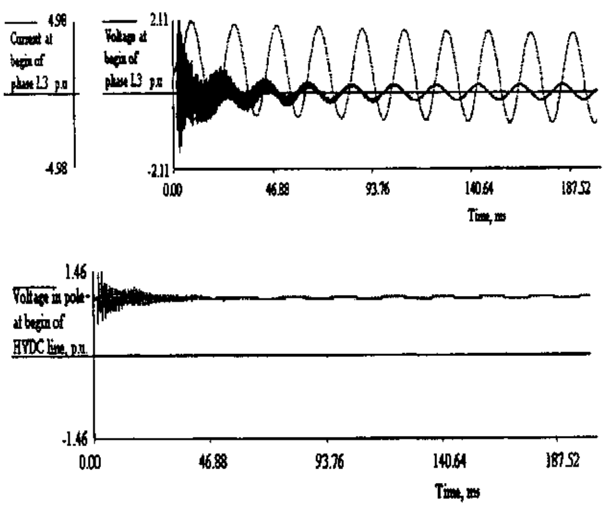

Fig. 4. Voltage and current waveforms in phase L2 of AC line and voltage in pole - of HVDC line during the three phase simultaneous fault at the end of AC line

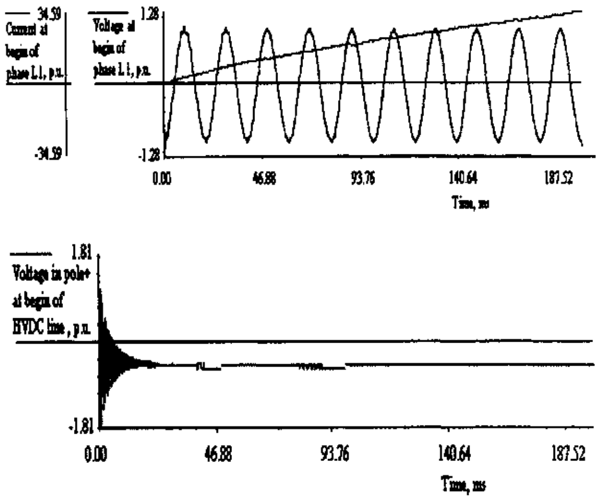

Fig. 5. Voltage and current waveforms in phase L1 of AC line and voltage at the beginning of pole + of HVDC line during the monopolar fault at the end of pole + of HVDC line.

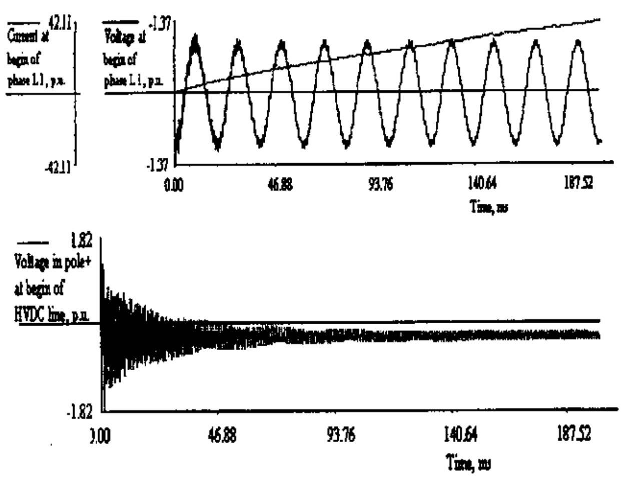

Fig.6. Voltage and current waveforms in phase L1 of AC line and voltage waveform in pole + of HVDC line during the bipolar fault at the end of the HVDC line

IV. CONCLUSIONS

During the disturbances in overhead electric line which are situated parallel - on the same right-of-way - (two lines with very small distance between them) or working on the same tower construction, can occur the overvoltages. The peak value of these overvoltages depends on type of disturbance and the geometry of the line. As mentioned above the overvoltages are results of the occurring of high frequency components in line voltage forms.

The maximal value of overvoltages occur for the case of investigations of HVDC and AC lines working with very small distance (fig. 1a):

- in HVDC line during the faults in this line - the maximum overvoltage factor was k_u=1.82 for monopolar fault (pole-earth) and k_u=2.15 for bipolar fault (pole-pole). The overvoltage factor for transient induced in HVDC line during the faults in AC line was lower than 1.46;
- in AC line during three phase fault in this line; overvoltage factor k_u=2.11; however the influence of HVDC line faults to AC line is important; the maximal overvoltage factor amounted 1,37

As results of the investigations for the lines working on the same tower construction (fig.1b) the overvoltage factors were:

- in HVDC line during the faults in this line; the maximal overvoltage factor equals 1.44 (for monopolar fault) and 2.12 (for bipolar fault). The overvoltage factors induced in this line during faults in AC were lower than 1.46;
- In AC line during the faults in this line; maximum overvoltage factor equals 2,17 for three phase fault; overvoltage factors for overvoltages induced from HVDC line (during faults in this line) were lower than 1.32.

For the investigated voltage levels (400kV AC and 500 kV DC) the maximum values of the overvoltages which are induced in one line during faults in second line are lower than the maximal value of the overvoltages occurring during intersystem faults. It can lead to conclusion that HVDC and AC lines with these voltage levels can work on the same tower constructions or as adjacent. Through suitable setting of reaction of protection relays is possible to avoid the outages of healthy lines. However it is not possible to assure the selective work of overvoltage protection system in one of two circuit in multi-circuit overhead line. The undumped circuit oscillations which appear in AC line can have a negative influence on the operation of control and protection system in the HVDC line.

Using NETOMAC program it is shown that all transients in high voltage system can be determine and the most severe conditions can be modeled without risk and with very flexible possibility to determine the performance of electrical equipment in the sound line under all possible fault conditions in the coupled high-voltage line working on the same tower construction.

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