ABOUT SWITCHING TRANSIENT PHENOMENA IN A 380 kV POWER SYSTEMS UNLOADED LINE

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ABSTRACT

This paper analyses the electrical transient phenomena in power systems, in particular for the switching of a 380 kV unloaded line. As a result of breaker switching, appear overvoltages, overcurrents and electrical fields, that are very danger for electrical equipment, environment and human life. The switching transient phenomena that are studied result from the circuit breaker switching of the 380 kV unload line located in KEPEZ-YATAGAN from Turkey. The simulation tool used was the PSCAD and MathCAD Programs, for T Model of line.

Keywords— Switching transients, Power systems, Unloaded line switching, Circuit breakers.

1. INTRODUCTION

The voltage stress in the switching devices depends on the network configuration [1-4]. Usually, the electromagnetic transient simulations are performed considering the unloaded line switching, also capacitor bank switching on the middle voltage part, using the circuit breakers [5-14].
The most common approach is to use the T-model (the Frequency-Dependent model), which should be considered in transient studies in order to obtain accurate results. The T-model of line is based on the travelling waves formulation, with the voltage disturbance reflecting the delay function and the wave-shape attenuation.
This paper is devoted to the evaluation of: the transient recovery voltages, the overvoltages on each phases and the electrical field as following of the unloaded line switching for different lengths of line. In this way were assumed seven different length values for the unloaded line.

2. ANALYTICAL APPROACH

The analysis of transient phenomena at the unloaded line switching can be made analytically by using the following mono-phase schematic circuit proposed by [1-5] (fig. 1),

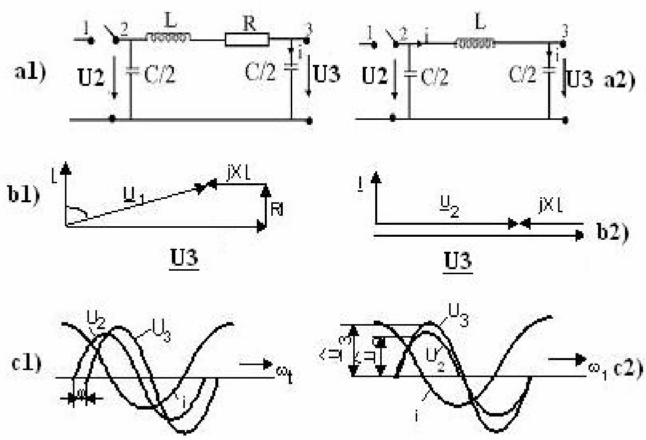

Fig.1
Disconnecting of the unload line
a_1) Model-equivalent a_2)Resistance neglected
b_1) Phasor-Diagram b_2) Phasor-Diagram
c_1) Instantaneous values c_2) Instantaneous values

where: both the general network and a reduced network with neglected resistances are held.
Switching transient phenomena of unload line can be expressed by figure 2 and following equations [6,7]:

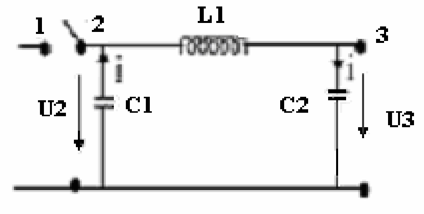

Fig.2.Electrical Model of unload line

$$\begin{cases} C_1 + C_2 = C \\ \dfrac{1}{2\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{L_1 \dfrac{C_1 C_2}{C_1 + C_2}}} \\ \dfrac{U_3}{U_2} = \dfrac{1}{\cos(\omega l / v)} = \dfrac{U_3}{U_3 - L_1 C_2 \omega^2 U_3} = \dfrac{1}{1 - L_1 C_2 \omega^2} \end{cases} \tag{1}$$

$$\begin{cases} C_1 = \dfrac{2C}{\pi^2} = 0{,}203\,C \\ C_2 = \left(1 - \dfrac{2}{\pi^2}\right)C = 0{,}797\,C \\ L_1 = \dfrac{L}{2\left(1 - \dfrac{2}{\pi^2}\right)} = 0{,}627\,L \end{cases} \tag{2}$$

The voltage u_2 can be calculated by [1-3]:

$$u_2 = u_{02} - \frac{1}{C_1}\int_0^t i\,\mathrm{d}t = \mathrm{L}_1 \frac{di}{dt} + u_{03} + \frac{1}{C_2}\int_0^t i\,\mathrm{d}t \tag{3}$$

where: u_{02} *and* u_{03} are the voltage values at the 2 and 3 terminals in comparison with ground, in moment of current interrupting.

Result:

$$u_2 = u_{02} - \frac{1}{C_1}\int_0^t \frac{u_{02} - u_{03}}{\sqrt{\dfrac{L_1}{C_R}}} \sin\left(\frac{t}{\sqrt{C_R \cdot L_1}}\right) dt \tag{4}$$

The maximum value is:

$$\hat{u}_2 = \hat{u}_{02} + 1{,}594\left(u_{03} - u_{02}\right) \tag{5}$$

The voltage Diagrams for u_1, u_2 and the Transient Recovery Voltage are illustrated in figure 3.

The maximum of the Transient Recovery Voltages will be:

$$\hat{u}_r = \left(u_1 - u_2\right)\max = 2\hat{U}_2 + 1{,}594\left(\hat{U}_3 - \hat{U}_2\right) \tag{6}$$

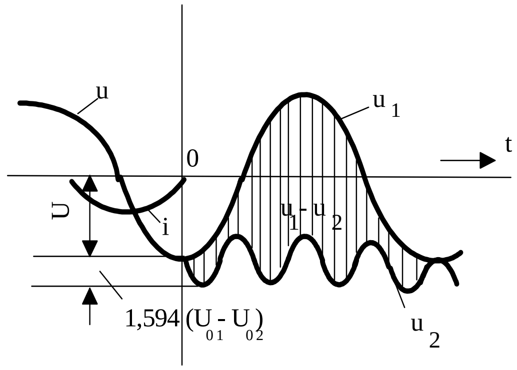

Fig.3
Transient Recovery Voltage

3. APPLICATION EXAMPLE

In order to analyse the transient overvoltages at disconnecting of an unloaded line in a 380 kV Electric Power System, it was studied by model from figure 4. This model was evaluated using the PSCAD Program.. The 380 kV High Voltage Line of the Power Systems (fig.4) presents for analysis: the voltage generators; the transformer; the transmission line modelling by T-Line Model (Frequency-Dependent Model); the busbar, the branch of capacitor bank, connected on generator, the circuit breakers for the switching of line and for switching of the capacitor bank. The transient phenomena were simulated with the circuit breaker on first position it was closed, following disconnecting operation. The 1st time was 0.205 [sec] and the 2nd time was 3 [sec]. For capacitor bank it were assumed discrete capacitance values from 30 μF until 150 μF with a step of 20 μF, considering a star connection.

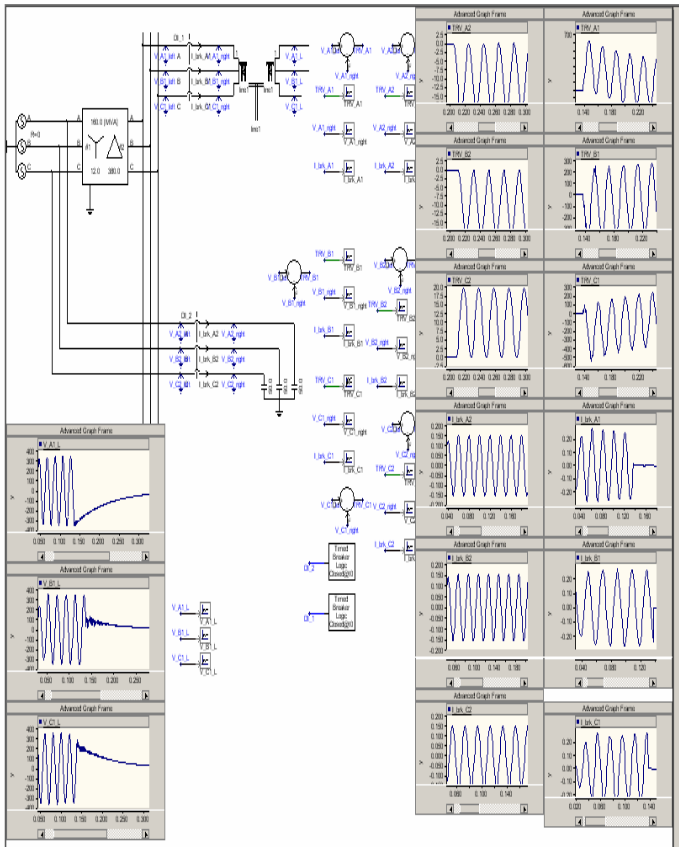

Fig.4.Modelling and simulation of the switching transient phenomena using PSCAD Program

4. RESULTS

The results are presented in the following tables and figures:

Table 1. Transient Recovery Voltages due to Switching Transient Phenomena in a 380 kV unload Line of Power Systems

l [km]	40	80	120	160	200	240	280
TRV_A[kV]	687,8	698,2	698,2	702,8	702,85	711,5	720,3
TRV_B[kV]	417,7	417,7	417,7	427,43	427,43	427,43	427,43
TRV_C[kV]	683,19	692,92	692,92	702,65	712,39	712,39	722,12

The table 1 presents the transient recovery voltages for different lengths of unloaded line disconnecting.

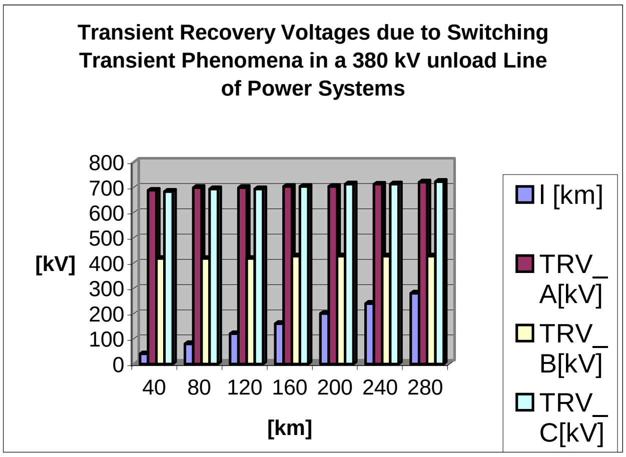

Figure 5. Transient Recovery Voltages at switching of unloaded line for different lengths

Table 2. Phase Voltages due to Switching Transient Phenomena in a 380 kV unload Line of Power Systems

l [km]	40	80	120	160	200	240	280
V_AL[kV]	315,04	315,04	315,04	322,12	322,12	329,2	336,28
V_BL[kV]	315,04	315,04	315,04	329,2	329,2	336,28	350,4
V_CL[kV]	316,81	316,81	320,35	332,74	332,74	332,74	344,25

In table 2 are presented the phase voltages for different lengths of line.

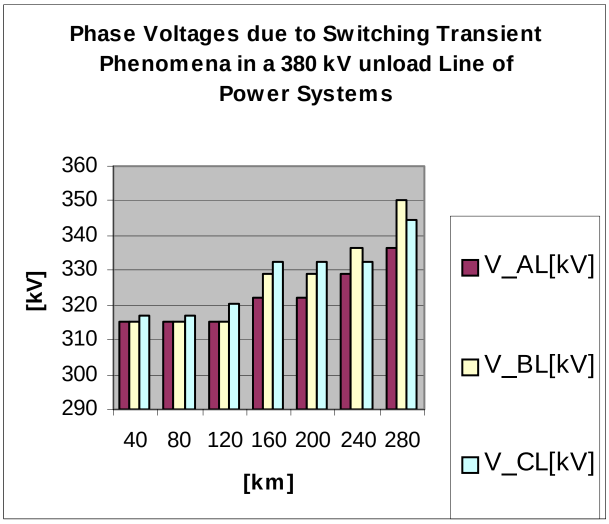

Figure 6. The phase voltages for different lengths of line

Table 3. Transient Recovery Voltages and the Phase Voltages due to Switching Transient Phenomena in a 380 kV unload Line of Power Systems

l [km]	40	80	120	160	200	240	280
TRV_A[kV]	687,8	698,2	698,2	702,8	702,85	711,5	720,3
TRV_B[kV]	417,7	417,7	417,7	427,43	427,43	427,43	427,43
TRV_C[kV]	683,19	692,92	692,92	702,65	712,39	712,39	722,12
V_AL[kV]	315,04	315,04	315,04	322,12	322,12	329,2	336,28
V_BL[kV]	315,04	315,04	315,04	329,2	329,2	336,28	350,4
V_CL[kV]	316,81	316,81	320,35	332,74	332,74	332,74	344,25

The table 3 presents the transient recovery voltages and the phase voltages due to switching transient phenomena in a 380 kV unloaded line of power systems.

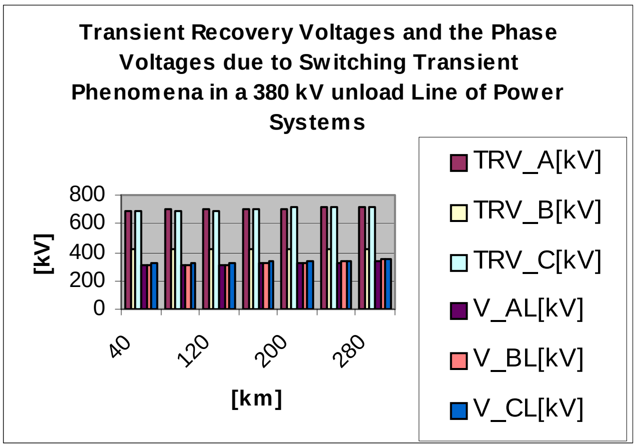

Figure 7. The Transient Recovery Voltages and the Phase Voltages due to Switching Transient Phenomena in a 380 kV unloaded Line of Power Systems

Table 4. The Phase Voltages and the Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level

l [km]	40	80	120	160	200	240	280
V_AL[kV]	315,04	315,04	315,04	322,12	322,12	329,2	336,28
V_BL[kV]	315,04	315,04	315,04	329,2	329,2	336,28	350,4
V_CL[kV]	316,81	316,81	320,35	332,74	332,74	332,74	344,25
E_AL[kV/m]	8,5	8,5	8,5	8,7	8,69	8,88	9,08
E_BL[kV/m]	8,5	8,5	8,5	8,89	8,88	9,08	9,46
E_CL[kV/m]	8,56	8,56	8,65	8,99	8,99	8,99	9,29
E_AL[kV/m]	13,42	13,42	13,42	13,72	13,72	14,02	14,32
E_BL[kV/m]	13,42	13,42	13,42	14,02	14,02	14,32	14,92
E_CL[kV/m]	13,49	13,49	13,64	14,17	14,17	14,17	14,66

In table 4 were presented the Phase Voltages and the Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level.

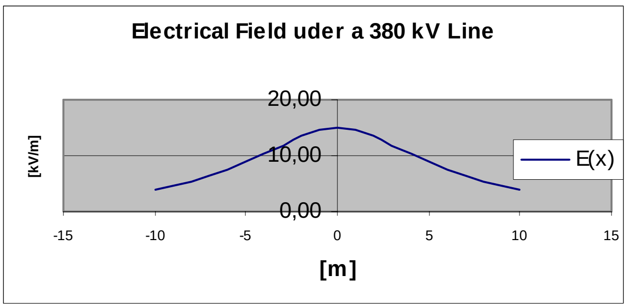

Figure 8. The Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level

Table 5.Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level

l [km]	40	80	120	160	200	240	280
E_AL[kV/m]	8,5	8,5	8,5	8,7	8,69	8,88	9,08
E_BL[kV/m]	8,5	8,5	8,5	8,89	8,88		9,46
E_CL[kV/m]	8,56	8,56	8,65	8,99	8,99	8,99	9,29
E_AL[kV/m]	13,42	13,42	13,42	13,72	13,72	14,02	14,32
E_BL[kV/m]	13,42	13,42	13,42	14,02	14,02	14,32	14,92
E_CL[kV/m]	13,49	13,49	13,64	14,17	14,17	14,17	14,66

The table 5 presents the Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level, for different lengths of line.

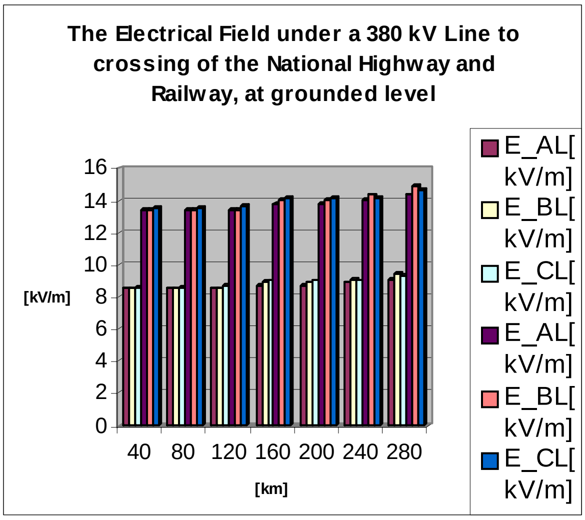

Figure 9. The Electrical Field under 380 kV Line to the crossing of the National Highway and Railway, at grounded level

The tables 1,2,3,4 and 5 show the influence of line length at unloaded switching about the Transient Recovery Voltages, Phase Voltages and Electrical Fields. It can be observed that values obtained are very high. These can generate danger influences about Electrical Equipment, Environment and Life. It is necessary to improve the maintenance of Lines of Power Systems and of Circuit Breakers switching in order to limit the maximum values of the switching Transient Phenomena.

Unload Line Disconnecting, MathCAD Program

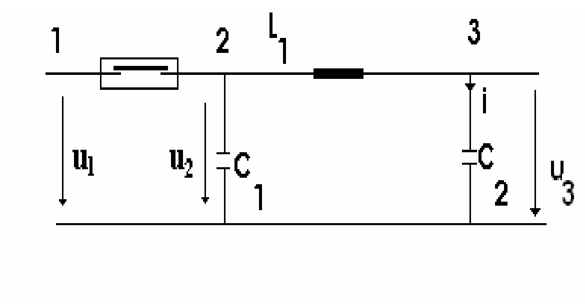

Figure 10. MathCAD disconnecting unloaded line model.

Line Parameters:

$$u2(t) := u02max + \frac{CR\cdot(u03max - u02max)\cdot\left(1 - \cos\left(t\cdot\frac{1}{\sqrt{CR\cdot L1}}\right)\right)}{C1}$$

$$urmax(t) := 2\cdot u1(t) + 1.594\cdot(u03max - u02max)$$

Line length: 280.km

$f := 50\cdot Hz$

$\omega := 2\cdot\pi\cdot f$

$l := 280\cdot km$

$Rtot := R1\cdot l$ $\quad Rtot = 1.885\cdot kg\cdot m^{2}\cdot s^{-3}\cdot A^{-2}$

$Xtot := X1\cdot l$ $\quad Xtot = 17.346\cdot kg\cdot m^{2}\cdot s^{-3}\cdot A^{-2}$

$Ytot := Y1\cdot l$ $\quad Ytot = 3.854\cdot 10^{8}\cdot kg\cdot m^{4}\cdot s^{-3}\cdot A^{-2}$

$C1 := 0.203\cdot C$ $\quad C1 = 2.491\cdot 10^{5}\cdot kg\cdot m^{4}\cdot s^{-2}\cdot A^{-2}$

$C2 := 0.797\cdot C$ $\quad C2 = 9.778\cdot 10^{5}\cdot kg\cdot m^{4}\cdot s^{-2}\cdot A^{-2}$

$L1 := 0.627\cdot L$ $\quad L1 = 0.035\cdot kg\cdot m^{2}\cdot s^{-2}\cdot A^{-2}$

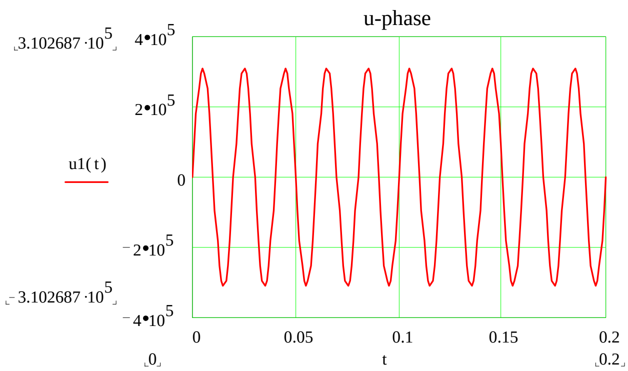

Figure 11. The phase voltage

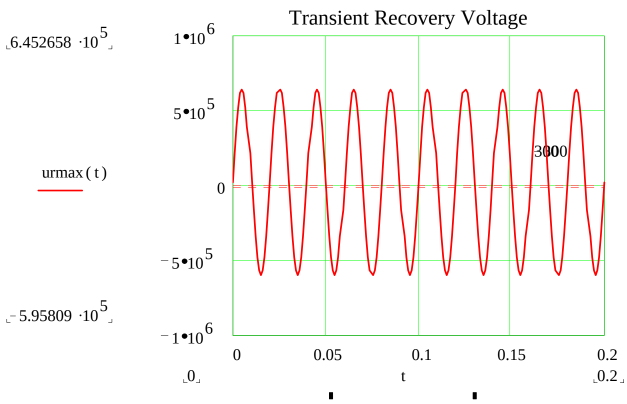

Figure 12. The Transient Recovery Voltage obtained by MathCAD Program

5. CONCLUSIONS

From the above results the following conclusions can be extracted:

- As following of the switching transients phenomena in Electrical Power Systems appear very danger disturbances for electrical equipment and for around environmental. Of these, the electrical fields, in last days, are in the preoccupations of the many specialists, thanks to their negative effect about equipment, environment and life [1-8,14].
- As following the unload line switching appear in Power Systems the big overvoltages (transient recovery voltages, 2.33 [p.u.]; phase overvoltages, 1.131 [p.u.], which all generate the electrical fields, with negative impact in Power Systems and around Environment.
- The results obtained for modelling and simulation are in according with theoretical solutions.
- The results obtained by PSCAD Model and MathCAD Model are in accordance (3.8 %).
- The result obtained for the maximal electrical fields due to a 380 kV unload line switching in Power Systems from Turkey, under line at grounded level (9.46 kV/m, at the crossing of the National Highway and 14.92 kV/m, at the crossing of the National Railway), show that they overtake the admissible limits recommended by the CIGRE and IEEE International norms [1,2,8].
- Therefore it is necessary to make investigations and to impose the limited methods.

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7. BIOGRAPHIES

Petre Tusaliu was born in Melinesti, Romania, at the 25th April 1949. He is full professor at University of Craiova, doctor in "switching transient phenomena". Is author and joint author of over 150 works of their area, has seven invention and innovation patents, four works for Education and two books published: "Electric Equipment - Design and Engineering" and "Genie des Hautes Tensions". He was CIGRE member (5 years) and their Curriculum vitae and activity have been included in "The International Directory of Distinguished Leadership, 1997", edited by "American Biographical Institute". Also, he have received the title "Man of the Year-1997", awarded by "American Biographical Institute-North Carolina-USA". He was specialising in Germany and in last years worked three stages, in co-operation at the Polytechnic Institute of Coimbra, Instituto Superior de Engenharia de Coimbra (ISEC), Portugal and, also, at the Technical University of Istanbul, for an important scientific co-operation was made possible due to the NATO Fellowship Research Programs. He has participated as member of many "Steering Committee" and "Editorial Board" of numerous International Conferences.