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 breakers 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 disturbances reflecting the delay function and the wave-shape attenuation.

This paper is devoted to the evaluation of: the transient recovery voltages, the over voltages 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
a1) Model-equivalent a2) Resistance neglected
b1) Phasor-Diagram b2) Phasor-Diagram
c1) Instantaneous values c2) 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

Disconnecting of the unload line
a1) Model-equivalent a2) Resistance neglected
b1) Phasor-Diagram b2) Phasor-Diagram
c1) Instantaneous values c2) Instantaneous values

where: both the general network and a reduced network with neglected resistances are held.
The voltage $u_2$ can be calculated by [1-3]:

$$u_2 = u_{d2} - \frac{1}{C_2} \int i \, dt = L_1 \frac{di}{dt} + u_{d0} + \frac{1}{C_2} \int i \, dt$$

where: $u_{d2}$ and $u_{d3}$ are the voltage values at the 2 and 3 terminals in comparison with ground, in moment of current interrupting.

Result:

$$u_2 = u_{d2} - \frac{1}{C_2} \int_{t_0}^{t} \left( u_{d3} - u_{d0} \right) \sin \left( \frac{t}{\sqrt{C_2 \cdot L_1}} \right) \, dt$$

The maximum value is:

$$\hat{u}_2 = \hat{u}_{d2} + 1.594 (u_{d3} - u_{d0})$$

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:

$$\hat{u}_t = (u_1 - u_2)_{\text{max}} = 2 \hat{u}_2 + 1.594 (\hat{u}_1 - \hat{u}_2)$$

### 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.

### 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

<table>
<thead>
<tr>
<th>l [km]</th>
<th>40</th>
<th>80</th>
<th>120</th>
<th>160</th>
<th>200</th>
<th>240</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRV_A [kV]</td>
<td>687.8</td>
<td>698.2</td>
<td>698.2</td>
<td>702.8</td>
<td>702.85</td>
<td>711.5</td>
<td>720.3</td>
</tr>
<tr>
<td>TRV_B [kV]</td>
<td>417.7</td>
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<td>427.43</td>
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</table>

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

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

<table>
<thead>
<tr>
<th>l [km]</th>
<th>40</th>
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<tr>
<td>V_AL [kV]</td>
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<td>329.2</td>
<td>336.28</td>
</tr>
<tr>
<td>V_BL [kV]</td>
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<td>329.2</td>
<td>329.2</td>
<td>336.28</td>
<td>350.4</td>
</tr>
<tr>
<td>V_CL [kV]</td>
<td>316.81</td>
<td>316.81</td>
<td>320.35</td>
<td>332.74</td>
<td>332.74</td>
<td>332.74</td>
<td>344.25</td>
</tr>
</tbody>
</table>

In table 2 are presented 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

<table>
<thead>
<tr>
<th>l [km]</th>
<th>40</th>
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</table>

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.

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

<table>
<thead>
<tr>
<th>l [km]</th>
<th>40</th>
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<tr>
<td>E_AL [kV/m]</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
<td>8.7</td>
<td>8.69</td>
<td>8.88</td>
<td>9.08</td>
</tr>
<tr>
<td>E_BL [kV/m]</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
<td>8.89</td>
<td>8.89</td>
<td>8.89</td>
<td>9.08</td>
</tr>
<tr>
<td>E_CL [kV/m]</td>
<td>8.56</td>
<td>8.56</td>
<td>8.65</td>
<td>8.99</td>
<td>8.99</td>
<td>8.99</td>
<td>9.29</td>
</tr>
</tbody>
</table>

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

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<tr>
<th>l [km]</th>
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</tr>
<tr>
<td>E_AL[kV/m]</td>
<td>13,42</td>
<td>13,42</td>
<td>13,42</td>
<td>13,72</td>
<td>14,02</td>
<td>14,32</td>
<td>14,92</td>
</tr>
<tr>
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<td>13,42</td>
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<td>14,02</td>
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<td>14,32</td>
<td>14,92</td>
</tr>
<tr>
<td>E_CL[kV/m]</td>
<td>13,49</td>
<td>13,49</td>
<td>13,64</td>
<td>14,17</td>
<td>14,17</td>
<td>14,17</td>
<td>14,66</td>
</tr>
</tbody>
</table>

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.

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:

\[
\text{C} \times \left( u_{03\text{max}} - u_{02\text{max}} \right) \frac{1}{1 - \cos \frac{t}{\sqrt{\text{C} \cdot \text{R} \cdot \text{L} \cdot 1}}}
\]

\[
u_{2}(t) := \frac{u_{02\text{max}}}{\text{C}}
\]

\[
u_{\text{max}}(t) := 2 \cdot u_{1}(t) + 1.594 \left( u_{03\text{max}} - u_{02\text{max}} \right)
\]

Line length: 280 km

\[f = 50 \text{ Hz}\]

\[\omega := 2 \pi f\]

\[l := 280 \text{ km}\]

\[R_{\text{tot}} := R_{1} \cdot l\]

\[X_{\text{tot}} := X_{1} \cdot l\]

\[Y_{\text{tot}} := Y_{1} \cdot l\]

\[C_{1} := 0.203 \text{ C}\]

\[C_{2} := 0.797 \text{ C}\]

\[L_{1} := 0.627 \text{ L}\]

\[\text{u-phase}\]

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 \[\text{p.u.}\]; phase overvoltages, 1.131 \[\text{p.u.}\]), which all generate the electrical fields, with negative impact in Power Systems and around Environment.
- The results obtained for modelling and simulation are in accordance 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.

6 REFERENCES

[13] Tusaliu, P., “Device for strains determination of electric breakers, when simple or multiple capacitor banks are switched”, Author’s certificate of invention no.92383/1987, Bucharest, Romania.

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.