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Harmonic voltages Following transient over voltages (in the event of a Lightning strike) on an electrical network.

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ABSTRACT : This research document shows the state of an electrical network following an atmosphericsurge (lightning). Startingfrom a real network has two sources and twolinesthat lead to twoloads CH1 and CH2, the lightning strike isconsidered to fall on the line L1, and the shockwavepropagatesalong the line towards the loads and the sources. Wedivideourstudyintotwo parts by simulating the network in the presence of lightning, first considering the unprotected network and secondlywith protection (surgearrester). The simulation results show by the curves and diagrams of the harmonicspectrum of the voltages, the effect of lightning on a network.

Index Terms: electrical network, overvoltage, harmonic, ATP / EMTP

I. INTRODUCTION

In this article, wewillstudy transient lightningsurges on a given network. The studyisdone in two parts, one without a protection system and the otherwith a protection system.

The lightning strikes whichfall on the overheadlines cause very important surgeswhichpropagatealong the lines to reach the stations located at the ends. It isnecessary to specify the insulation of the equipment and to determine the protection of the network (lightningarresters, spark gaps) to make the risk of equipmentfailureeconomically acceptable due to lightning. Lightning overvoltagesalso trigger overheadlineswhichdegrade the qualityof service at network delivery points by givingrise to brief cuts or voltage dips.

This phenomenon leads us to study by simulation thesetwo cases mentionedabove : with and without protection following a lightningwhichfalls on an overhead line. We can seefrom the simulation the voltage patterns during the presence of faults (lightning) and wealso show the harmonic voltage levels.

In thisclassic transient simulation approach, we use the ATP / EMTP software to makeourstudy a reality.

When a lightning strike hits an object on the ground, thatobjectbecomesconnected to the storm cloud by an electrifiedchannel. In most cases, the channeltraversedisfrom the ground to the cloud by a first currentdischarge, then by severalotherdischarges, generally of lessintensity. At the level of the groundobject, the lightning strike can beseen as acurrent source whichinjects a first impulse followed by severalother impulses. During transient studies, theseadditional impulses are generally not considered, becausethey are oftenmuchless restrictive than the first impulse. The peak value (intensity) of the current of the first pulse I_{fl} is a random one which can take a value between a few kA and $200kA$, with a median value of $31kA$. The edge time istypically a few microseconds. The mid-tail time of the first pulse isalso a random variable, itsmedian value is $75\mu s$.

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Presentation of the study network

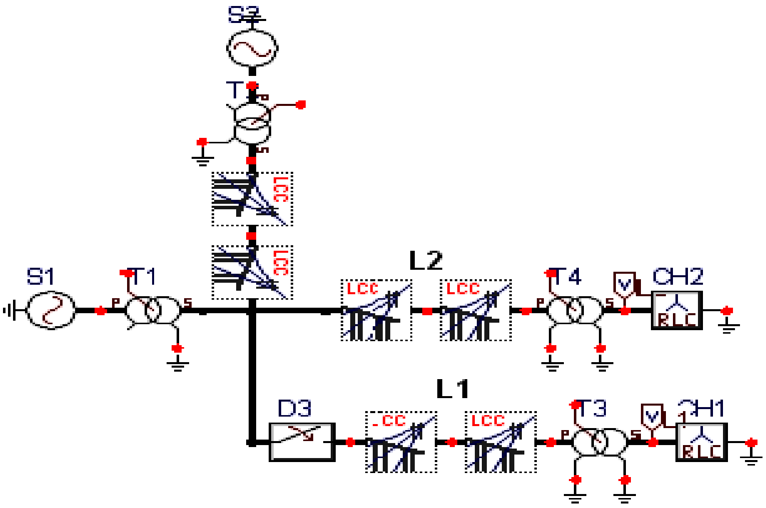

Figure 1 : Diagram of the network in general on EMTP

Consider a network made up of two 1 MVA generators, rated at 5kV. The generator S1 isconnected by a step-up transformer T1 (5 / 20kV) of 1MVA and short-circuit voltage of 10%, to threethree-phase lines of 20kV L1, L2 and L3 respectively 6km, 4km and 3km long (R = 0.2 Ω / km ; X = 0.4Ω / km ; Y = 3µS / km) each.

The generator S2 isconnected by a step-up transformer T2 with the sameproperty as T1 to the previous line L2. The loadsconnected to the other end of the line L1 and L3 are respectively CH1 and CH2. Wenoted a voltage of 0.4kV at the terminals of eachloadwhichis inductive and draws a power of 1 MVA for CH1 and 0.75MVA for CH2 with a power factor of 0.8 each.

Characteristics of transformers

For the step-up and step-down transformersthatwe use, weconsidertheirparameters as shown in the following table :

Settings	T1 and T2	T3 and T4
Apparent powers [MVA]	1	1
Transformation ratio	5/20	20 / 0.4
Ironlosses P_{mag} [MW]	0.2%	0.2%
Nominal current P_{cu} losses [MW]	0.6%	8%
Leakage inductance	12.8%	2, 5%
Magnetizing R_{mag} resistance [Ω]	12500	200000
Primaryresistance R1 [Ω]	0.075	16
Resistance to secondary R2 [Ω]	0.0012	0.0064
Primary inductance L1 [mH]	5	32
Secondary inductance L2 [mH]	83	0.012

Characteristics of alternators at sources S1 and S2

The parameterspresented in the following table 10.1 are the parametersnecessary for the simulation with EMTP. Both sources have the samecharacteristics:

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Settings	S1 and S2
$S_n[MVA]$	1
$V_n[kV]$	5
$f[Hz]$	50
A	0
T_{start}	-1
T_{stop}	1

CH1 load and CH2 loadcharacteristics

Settings	CH1 loads	CH2 loads
Apparent power [MVA]	1	0.75
Active power [MW]	0.8	0.6
Reactive power [MVAR]	0.6	0.45
Nominal voltage [kV]	0.4	0.4

Line characteristics

Settings	L1	L2	L3
Operating voltage [kV]	20	20	20
$R_0[\Omega/km]$	0.2	0.2	0.2
$X_0[\Omega/km]$	0.4	0.4	0.4
$Y_0[\Omega/km]$	3	3	3
Length [km]	6	4	3

Lightning strike simulation

On the same network, considering a lightning strike falls on one of the phases of line L1 at time t = 0.08s. Wewillcharacterize the lightningcurrent by itspeak value 3000V and whichlasts 1ms. thislightningismodeled by the currentcurvescalled 10 / 350µs according to IEC 61312-1.

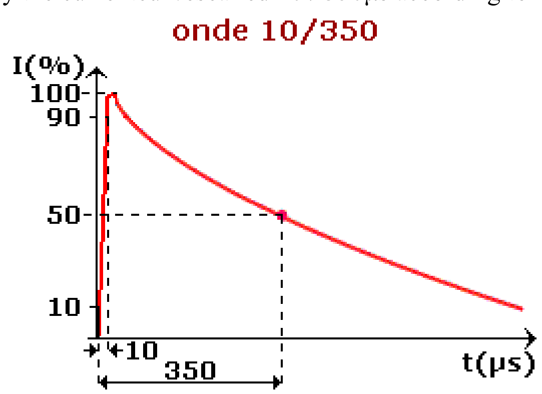

Figure 2:Characteristiccurve of the 3 lightningwaves

And we have the Followingresults :

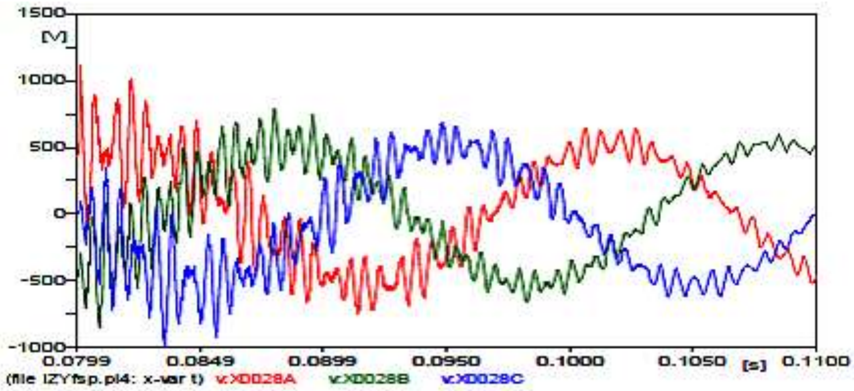

Figure 3: Voltage pattern at the input of load CH1

The three phases undergo a superposition of the shockwavewhich causes pollution of the network without a protection system whichattenuates the effect of the shockwave. The peak value to beexceeded 1200V is 300% of the nominal value. This cloudinessis due to the successive discharges of lightning (first to fourth arc). Wealsoidentify the presence of high frequencyphenomenon.

Any look in Figure 10.25, gives us the spectral representation of the harmonics by phase whichis possible thanks to a Fourier seriesdecomposition of the voltage waves, as follows:

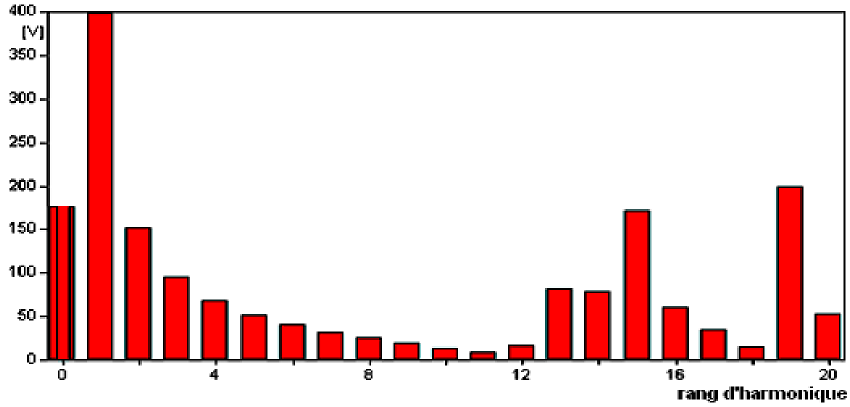

Figure 4 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1A

According to the spectral analysis, the lightningspectrumisverypredominant at high frequency. This shockwave can cross all the entire networks if thereis no surgearrester in a certain node of the network. It istruethat the duration of the shockwaveonlylasts a few µs but can cause a lot of damage for consumers.

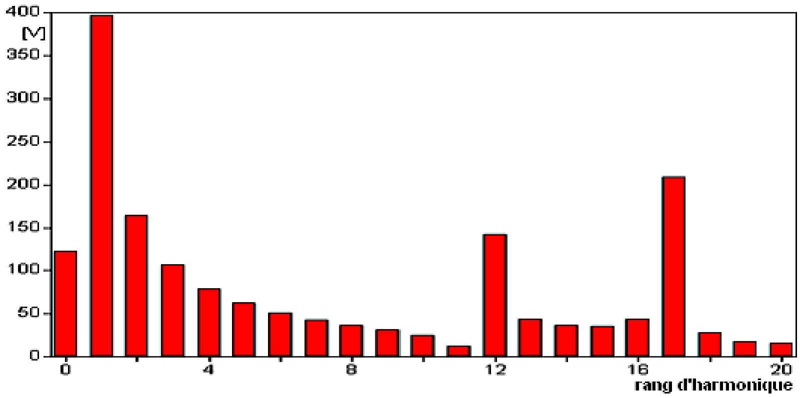

Figure 5 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1B

For phase L1B, we have the same pace but the rankswhich are preponderantwhichdifferentiatethem.
Ranks 2, 12 and 17 are the mostvaluable. The effect of the shockwavestillremainsthere for phase L1B.

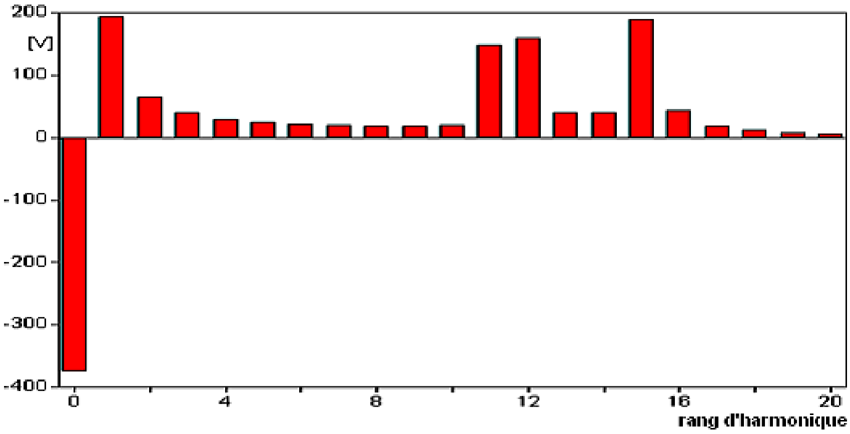

Figure 6 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1C

Lightning strike simulation on line L1 in the presence of protection systems

Nowlet'sinstall a ZnO type surgearrester. Figure 10.35 shows itselectricalcharacteristics.
The ZnO type is the mostusedbecause of the shape of itsfunction U = f (I) whichisalmost flat within a certain range of variation of I.

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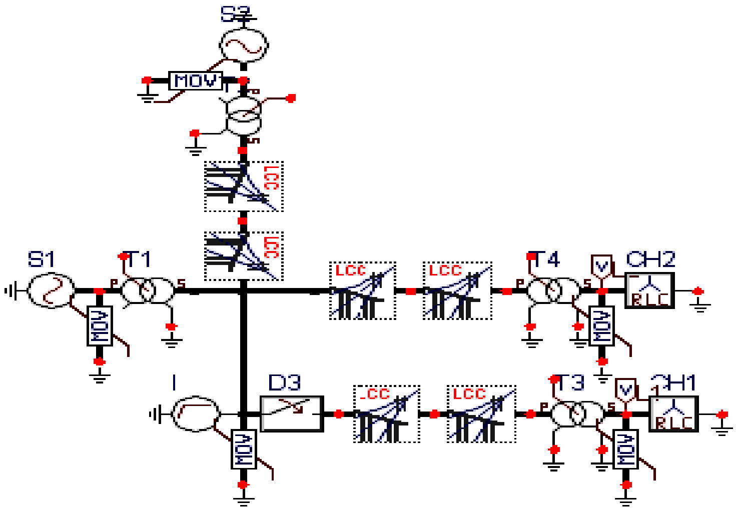

Figure 7 : Network diagram in simulationwith protection

ZnOsurgearrestercharacteristics

Settings	**Surgearrester for sources**	**Surgearrester at line entry**	**Surgearrester at the end of lines L1 and L3**
V_{ref} = Reference voltage [V]	6000	30,000	600
V_{flash} = Bypass voltage [pu]	-1	-1	-1
V_{zero} = Initial tension	0	0	0
COL = multiplicative factor for the coef	1	1	1
SER = Number of blocks in series	1	1	1
$ErrLim =$	0.03	0.04	0.05

The results are as follows :

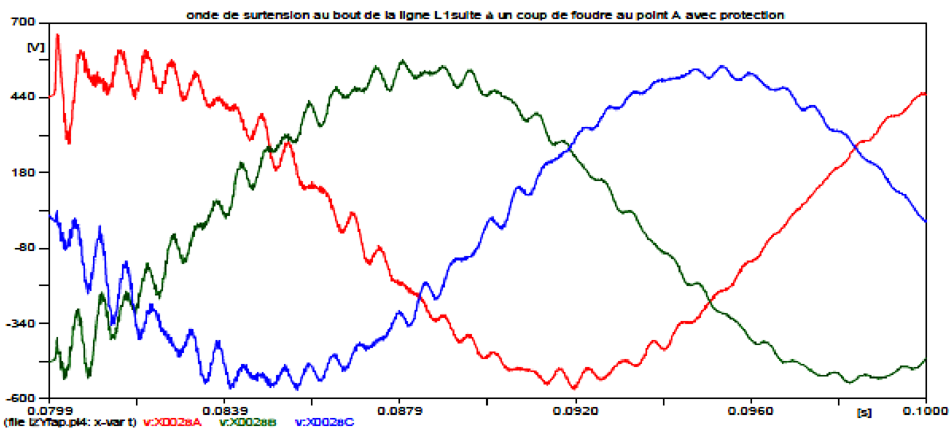

Figure 8 : Voltage patterns at the input of load CH1

We can clearlysee the effect of the surgearrester in a network. The attenuation of the peak values of the overvoltages of each phase (does not exceed 700V), the disappearance of the

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majorities of high frequencyphenomena and the rapiddamping of faults (the disturbancedisappears in lessthan one period.

Any look in Figure 10.36, gives us the spectral representation of the harmonics by phase whichis possible thanks to a Fourier seriesdecomposition of the voltage waves, as follows:

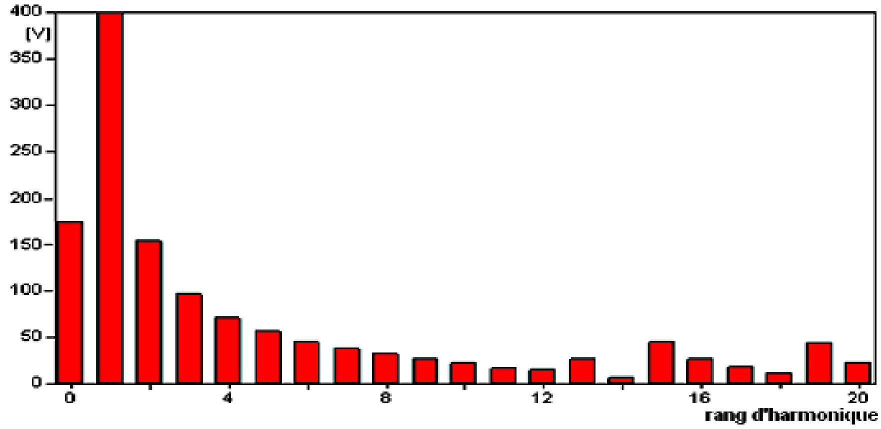

Figure 9 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1A

The surgearresterimproves the sinusoidal voltage wave at best, but itisnecessary to installharmonicfilters to respect the spectral purity of the voltage on the electricalenergy network. The spectral representation of the harmonic voltage in the presence of the protection shows us that the peaks of the harmonics are attenuated (not more than 150V). But the effect of the shockwaveisstillpresent at the fifteenth and nineteenthharmonic.

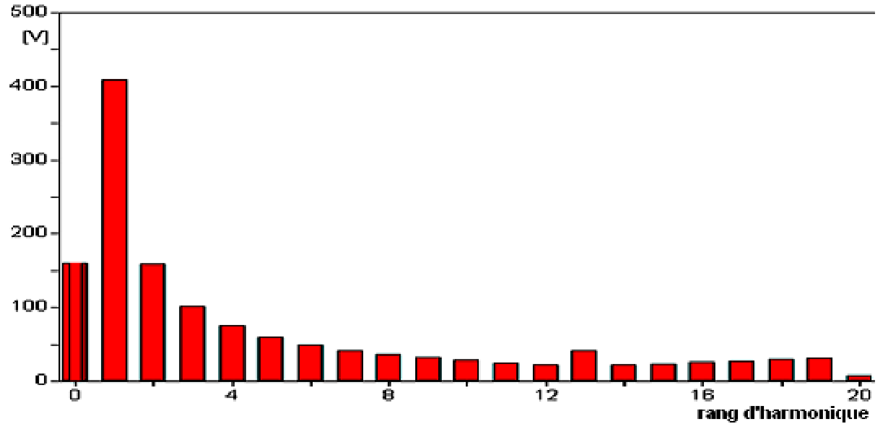

Figure 10 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1B

The presence of a protection system weakened the harmonicswhichonlymanifesteditselfduring 5.9ms. For phase L1B, the effect of shockwaves are alsoweakened (lessthan 50V).

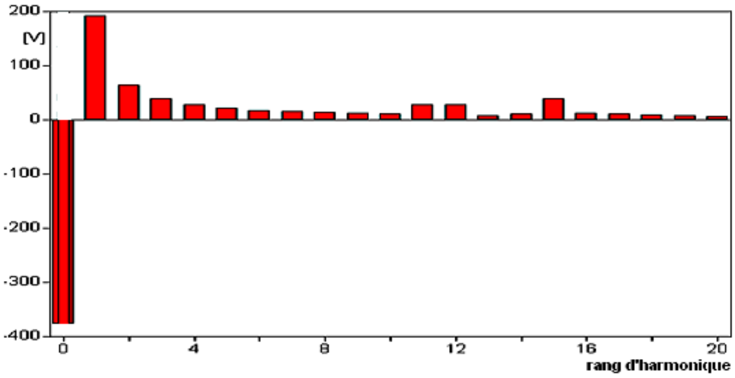

Figure 11 :Harmonic voltage level or voltage spectrum and phase betweenfundamental and harmonic for phase L1C

The harmonic for phase L1C presentsalmostnothingbecause the mostpreponderantpeak has only a value lessthan 30V.

CONCLUSION

After the simulations wehad made, the overvoltagecaused by lightning on a charged line isvery important. The transient lightningsurgeis the largest of all the surges, as it can reach up to 2.5 to 3pu of the nominal value over anythingwhen the network is not protected. Wealsosawthat the surgewavepropagates up to severalkilometers as wesee at point A of line L2. The injection of lightningcurrentinto the network causes a distortion of the fundamentalwaves and whichgives the harmonic voltage. In view of the transient phenomena, protection devices are necessary but must beprioritized in order to ensure a pure sine wave voltage at the consumers.

SOME ADVANTAGES OF THE ABOVE RESULTS

- Knowledge of the importance of atmosphericdisturbancessuch as lightning on electrical networks
- The importance of protection systems on electrical network disturbances (as in our case here, the surgearrester)
- Knowledge of voltage pattern duringfaults and harmonicsthat affect the network

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