

SIMULATION OF COMPENSATION OF CORONA CURRENT HARMONIC IN EHV OL USING MATLAB

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Abstract- AC corona losses characteristics in Matlab Simulink are modeled in this paper. Harmonic components of the corona current are also analyzed. Comparisons of data modeling results with the numerical calculated and experimental data are presented as well.

Keywords: AC Corona, Corona Model, Increment of Line Capacity, Harmonic Spectrum.

I. INTRODUCTION

The problems associated with the higher harmonics of the corona in overhead line extra high voltage (EHV OL) are not fully investigated. The study of the harmonic structure of the corona current is necessary for payments surge in long lines in the analysis mode EHV OL at the higher harmonics when measuring power loss at the crown EHV OL based on harmonics, when monitoring power quality.

Higher harmonics generated EHV OL caused by corona AC, affect the quality of performance of power. It is known that the capacity of the crown of the HV phase rises near the wires [1-5]. This leads to an increase in the generation of reactive power in high voltage power lines. In [1-7] studied the physical processes accompanying corona discharge on wires high voltage overhead lines.

Usually reactive corona effect model is performed as an additional element to the geometrical line capacitance. Line voltage of 220 kV and above, at which the wires during operation occurs crown are harmonic current sources [1-4].

It is known [1-5] that corona current in the spectrum, in addition to the fundamental frequency the third harmonic of current contained. This current is approximately 30% of the first current harmonic. The calculations and modeling of the corona system is represented in the form of compensated current crown.

II. CORONA MODELS

For study the line current harmonics caused by the corona wires, O.V. Shcherbachev and G.N. Aleksandrov [5] proposed a circuit diagram shown in Figure 1. In the model scheme C_{c0} is geometric capacity of lines, E_1 and E_2 are backwater voltage equal to the initial corona voltage.

When the line voltage, exceeds the initial voltage line scheme including the connected C_{c1} , C_{c2} and R , then the C_{c1} imitates the formation of space charge in the corona line; and $R-C_{c2}$ element simulates the movement of the space charge in the corona line, accompanied by energy losses. The $R-C_{c2}$ element in accordance with the real process corona current through line supports the crown model and energy dispersal charge after passing through a maximum (after blocking diode) for some time. Accordance crown models to the real process is achieved by an appropriate choice C_{c2}/C_{c1} and model constant.

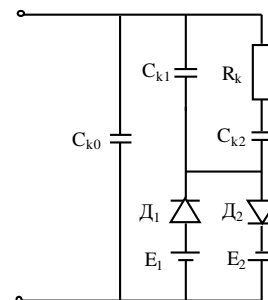


Figure 1. Schematic model of the corona

$$T = \frac{C_{c1}C_{c2}R}{C_{c1} + C_{c2}} \quad (1)$$

The method of selection of model parameters, which provides the required dynamic characteristics presented in [5]. Necessary model is depending on $P = f(U/U_n)$ and $P = F(f)$ selected by change in the ratio of model parameters C_{c2}/C_{c1} and the T . The absolute values of the model parameters are selected by comparing the loss dependency from overvoltage's multiplicity of relative to the initial voltage of the crown on the real corona line in the model in accordance with a predetermined scale modeling.

The first method is based on $U-q$ characteristics of the corona [1-5]. To simplify the calculations, this method is practically inapplicable. Modeling compensated corona current on a physical model based on the removal of the crown current waveform and harmonic spectrum of the corona current and the processing of the results. For this, Matlab Simulink [8] software is used.

In the future, this model uses the model to determine the parameters of the HV and EHV studies corona effect on the quality of electricity.

Equivalent circuit of line corona contains additional nonlinear elements - conductance (g) and capacity (ΔC) in addition to the L and C . They can be identified if the power loss characteristic corona $P_c = f_1(U)$ and the angle shift of the first harmonic of the corona current in relation to voltage $\varphi_1 = f_2(U)$ are known. Thus:

$$g = \frac{P_c}{U^2}, \quad \omega \cdot \Delta C = g \cdot \tan \varphi_1 \quad (2)$$

Additional capacity is defined by the equation:

$$\Delta C = \frac{\Delta P_c}{\omega U^2} \tan \varphi_1 \quad (3)$$

where, ΔP_c is corona power losses in power line; ω is angular frequency; U is line voltage; and φ_1 is angle shift of the first harmonic of the corona current in relation to voltage $\varphi_1 = f_2(U)$ are known. The generalized dependence of the corona power loss for a single-phase line, obtained experimentally, approximated by the expression [6]:

$$\Delta P_c = 1.05 \times 2\pi f C^2 U_0^2 / n \varepsilon_0 [1 + (n-1) \times 0.14] \sqrt{U/U_0} (U/U_0 - 1) \quad (4)$$

where, C is line capacity F/km; ε_0 is the dielectric constant of air 8.86×10^{-9} F/km, U and U_0 are the corona's operating and initial voltage in line, f is network frequency; and n is the number of wires in phase.

III. CALCULATED EXAMPLE

In order to evaluate the effectiveness of the proposed method, numerical experiments were carried out. Corona's compensated current model for 500 kV overhead lines for the phase design 3×AS330/43, with the splitting step 40 cm and the parameters $r_0 = 0.029$ Ohm/km, $x_0 = 0.299$ Ohm/km, $c_0 = 11.9 \times 10^{-9}$ F/km, and $b_0 = 3.74 \times 10^{-6}$ Sm/km is shown in Figure 2.

The EHV OL equivalent model parameters are taken identical to the original model. In this case $C_{c1} = 6.5 \times 10^{-9}$ F, and $C_{c2} = 13 \times 10^{-9}$ F. The resistance pattern was determined from the Equation (1) at $T = 0.00166$ sec. It has a value of $R = 383080$ Ohm at $U_{n0} = U_{fmax} = 408.248$ kV, $U_{over}/U_{fm} = 1.1$.

For this model, the initial calculations were made when setting the $U/U_0 = 2$, $C_{c2} = C_f = 12 \times 10^{-9}$ F and the condition $C_{c2}/C_{c1} = 2$, $C_{c1} = C_{c2}/2 = 12/2 = 6 \times 10^{-9}$ F. From the Equation (1), $R = 415000$ Ohm. The Matlab simulation results are shown in the first row of Table 1. Comparing the corona power losses 425 kW with losses based on generalized characteristic (460 kW), calculations were carried out at $C_{c2} = C_f = 13 \times 10^{-9}$ F and $C_{c2}/C_{c1} = 2$, $C_{c1} = C_{c2}/2 = 12/2 = 6.5 \times 10^{-9}$ F. From Equation (1), we obtain $R = 383080$ Ohm.

IV. RESULTS OF COMPENSATED CURRENT MODELING IN MATLAB

Results of the equations modeling in Matlab Simulink are shown in Figure 3. The first graph in Figure 3 is the AC voltage source voltage equal to $500\sqrt{2}/\sqrt{3}$ kV, the

second graph is the current in the circuit TC1, the third graph is current in the circuit $R-C_{c1}$, the fourth graph is the total current in the corona model.

The results of corona current simulation depending on the overvoltage's multiplicity U_{over}/U_{fm} in Matlab according to model in Figure 2 are given in Table 2.

For determine the initial voltage of the crown used the power loss characteristic of Equation (3) based on generalized characteristics. The simulation results of the amplitude of corona current harmonics depending on AC cycle at a multiplicity of overvoltage 2 are shown in Figures 4-6.

The amplitudes and phase shift angles depending on the of overvoltage's multiplicity compensated corona current harmonics are given in Table 3. These compensated corona current shown in Table 3 coincide with the experimental data [1, 4, 5].

Increments capacity defined using corona simulation results in Matlab (Tables 2 and 3) from the Equation (3). These data are presented in Table 4. Therefore, the modeling in Matlab allows studying the phenomenon of the crown on the wires.

V. CONCLUSIONS

1. The model of the crown compensated current EHV OL developed in Matlab. The method for selection AC corona equivalent model parameters presented.
2. Compensated current model of the crown in Matlab can be used for formation of the HV models EHV OL and analysis of the impact on the power quality.
3. AC model crown EHV overhead lines allowed determine the corona power losses, an additional capacity of EHV OL, investigate the corona current harmonics parameters of depending on the overvoltage.

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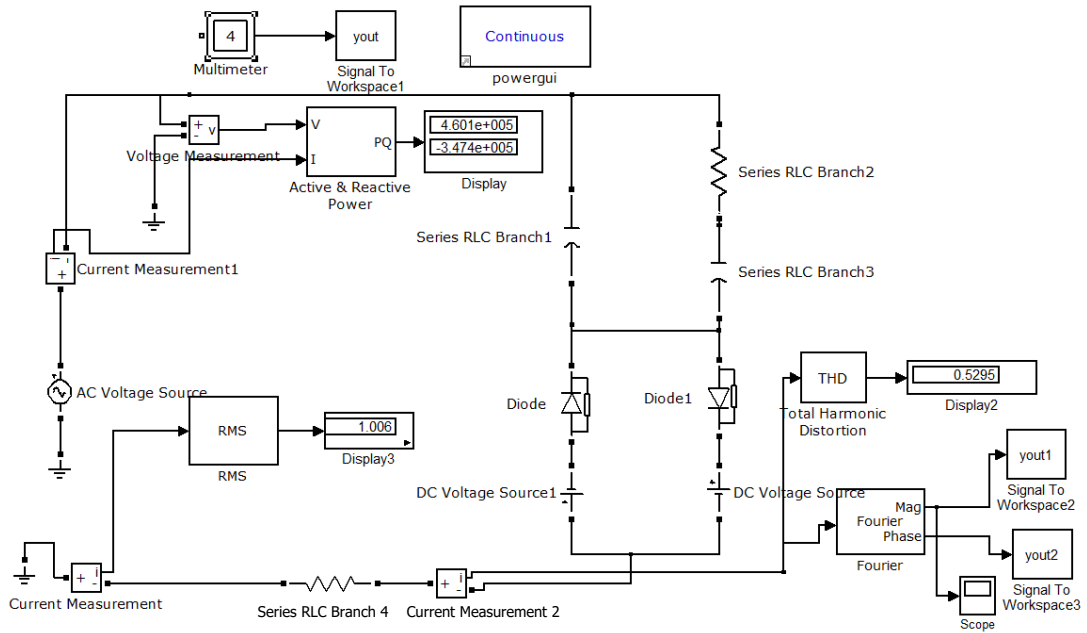


Figure 2. Compensated current model of corona in Matlab Simulink

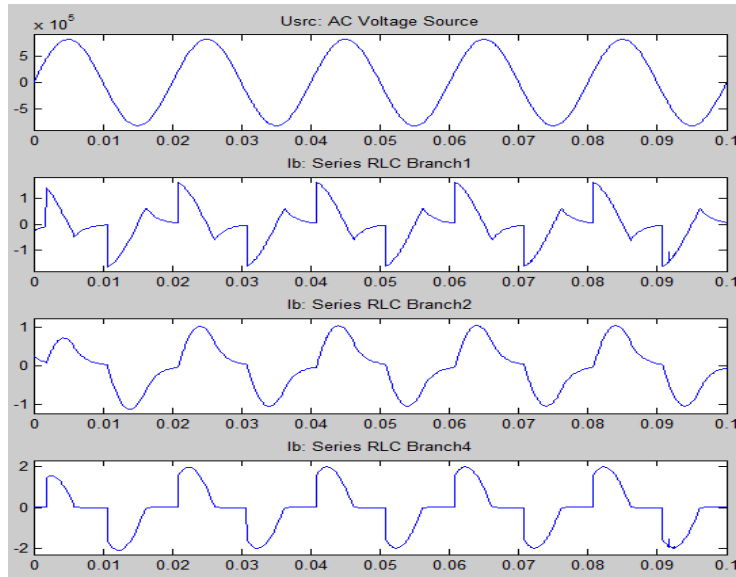


Figure 3. Corona current simulation results in Matlab

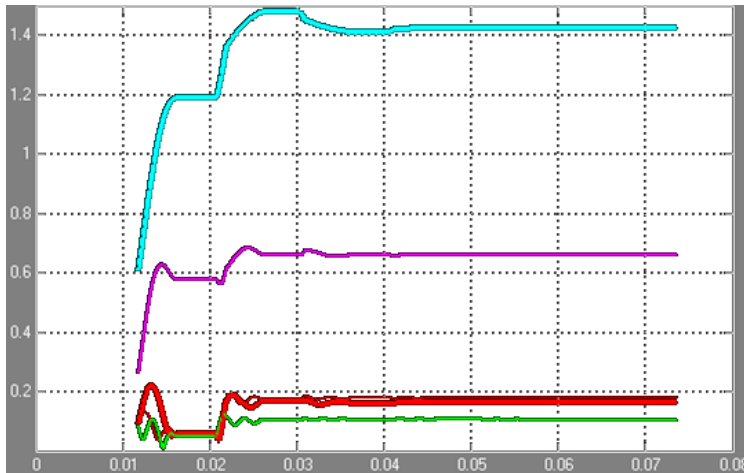


Figure 4. Compensated corona current harmonics amplitudes

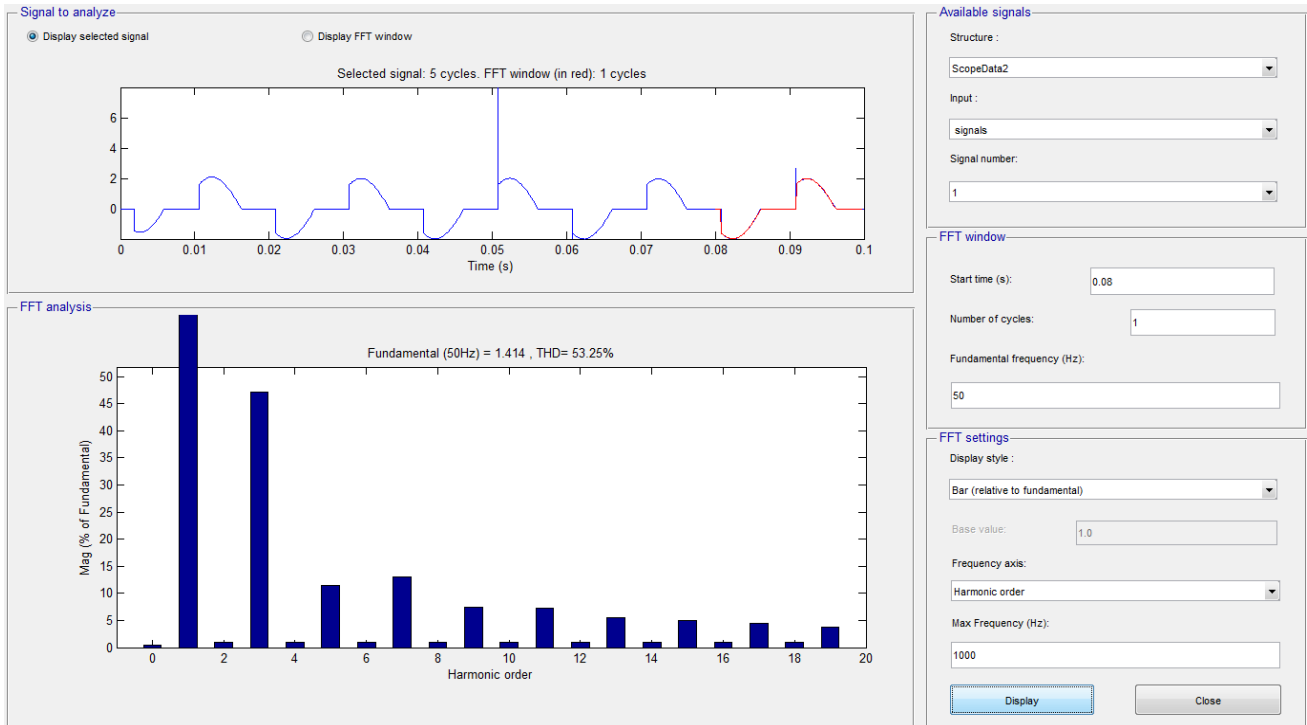


Figure 5. Corona current harmonics spectrum in Matlab

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Sampling time = 0.000173913 s
Samples per cycle = 115
DC component = 0.002353
Fundamental = 1.42 peak (1.004 rms)

Total Harmonic Distortion (THD) = 52.51%

Maximum harmonic frequency
used for THD calculation = 2800.00 Hz (56th harmonic)

    0 Hz (DC) :           0.17%    270.0°
 16.6667 Hz      0.53%    73.0°
 33.3333 Hz      0.49%    88.5°
 50 Hz (Fnd) :    100.00%   35.5°
 66.6667 Hz      0.42%    56.3°
 83.3333 Hz      0.56%    73.2°
 100 Hz (h2) :    0.40%   255.6°
 116.667 Hz      0.34%    44.7°
 133.333 Hz      0.61%    56.9°
 150 Hz (h3) :    46.76%  -66.9°
 166.667 Hz      0.42%    52.8°
 183.333 Hz      0.62%    28.1°
 200 Hz (h4) :    0.57%   209.3°
 216.667 Hz      0.51%    33.2°
 233.333 Hz      0.56%     8.6°
 250 Hz (h5) :   11.37%  -80.2°
 266.667 Hz      0.55%     8.5°
 283.333 Hz      0.49%    -4.0°
 300 Hz (h6) :    0.50%   168.6°
    
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Figure 6. Corona current harmonics spectrum

Table 1. Results of crown current modeling in Matlab in Figure 1 for selection of the model parameters when $U_{over}/U_{fm} = 2$

No	$C_{c1}, 10^{-9} F$	$C_{c2}, 10^{-9} F$	R_m, Ohm	I_{max}, A	P_{mod}, kW	$Q_{mod}, kVAr$
1	6	12	415000	1.8	425	325
2	6.5	13	383080	2.0	460	347
3	7	14	375480	2.1	490	350

Table 2. Results of compensated crown current modeling in Matlab

No	U_{over}/U_{fm}	U_{ims}, kV	P_{mod-fs}, kW	$Q_{mod-fs}, kVAr$
1	1.05	428.6607	8.202	1.773
2	1.1	449.0731	21.33	6.136
3	1.2	489.8980	51.07	19.83
4	1.3	530.7228	86.87	40.17
5	1.4	571.5476	127.8	66.78
6	2	816.4966	459.70	347.3

Table 3. Amplitude and phase shift angles of compensated crown currents harmonic

Harmonics	Amplitude and phase shift angles of compensated crown currents harmonic U_{over}/U_{fm}							
	1.05		0.2		1.4		2	
	U_i	Ψ_i	U_i	Ψ_i	U_i	Ψ_i	U_i	Ψ_i
1	0.05	11.6	0.23	19.9	0.52	28.5	1.42	37.2
3	0.05	214.5	0.18	241.8	0.36	267.8	0.66	-61.8
5	0.04	58.1	0.11	112.4	0.15	161.9	0.16	-70.6
7	0.04	262.7	0.07	2.9	0.07	120.3	0.18	244.4
9	0.03	109.1	0.05	261.9	0.08	42	0.11	236
11	0.02	-41.4	0.03	156.3	0.05	-36.3	0.1	190.2
13	0.02	173.4	0.03	76.4	0.05	-89.9	0.08	178.9
15	0.01	36.2	0.04	-28.5	0.04	188.4	0.07	136

Table 4. The results of capacity increment modeling of the line under voltage 500 kV

No	U_{over}/U_f	U_{im} , kV	P_{mod-f} , kW	Q_{mod-f} , kVAr	ϕ_1 , rad	ΔC , 10^{-9} F/km	$\Delta C\%$
1	1.05	428.66	8.20	1.77	5	0.025	0.21
2	1.1	449.07	21.33	6.14	10	0.118	1.00
3	1.2	489.90	51.07	19.83	15	0.363	3.05
4	1.3	530.72	86.87	40.17	20	0.715	6.01
5	1.4	571.55	127.80	66.78	25	1.16	9.76
6	2	816.49	459.70	347.30	34	2.96	24.88
7	2.2	898.15	601.80	487.30	35.7	3.29	27.64

BIOGRAPHIES



Ashraf B. Balametov was born in Qusar, Azerbaijan, on January 27, 1947. He received the M.Sc. degree in the field of Power Plants of Electrical Engineering from the Azerbaijan Institute of Oil and Chemistry, Baku, Azerbaijan in 1971, and the Candidate of Technical Sciences (Ph.D.) degree from Energy Institute named G.M. Krgiganovskiy, Moscow, Russia and Doctor of Technical Sciences degree from Novosibirsk Technical University, Russia in 1994. He is a Professor in Azerbaijan Research Institute of Energetics and Energy Design, Baku, Azerbaijan. His research interests are steady state regimes, optimization, and power system control.



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