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SIMULATION OF IMPULSE VOLTAGE GENERATOR IN DIFFERENT IMPULSE VOLTAGES FOR TESTING OF UNDERGROUND POWER CABLES IN MATLAB/SIMULINK

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ABSTRACT

In this paper both equivalent circuit as well as Marx circuit models of impulse voltage generator for testing of underground power cable is analyzed by simulation method. The capacitance value of underground cable has been taken as load to the impulse voltage generator. The comparison on the R1 and R2 that is front and tail resistance respectively has been done for a standard impulse wave (1.2/50µs). Further the effect on the front and tail resistance has been also analyzed for the different rating of the underground power cable.

Keywords: *Equivalent circuit model of impulse voltage generator, Marx circuit model, capacitive load, underground power cables, Matlab/ Simulink.*

I. INTRODUCTION

Underground power Cables are very important electrical apparatus for transmission of electrical energy by underground means. Hence the impulse testing of underground power cables is considered here. The impulse test voltage level is determined by the voltage rating of underground power cable. The applied impulse test voltage level is 4 to 5 times of the normal operating voltage value of underground cable and it has to withstand five applications without any damage. Usually, after the impulse voltage test, the power frequency dielectric power factor test is done to ensure that no failure occurred during the impulse test. To test the ultimate impulse strength, apply increasing amounts of impulse voltage until failure of underground cable occurs during the tests. The damage may not be immediately visible, so we observed it with the help of high frequency oscilloscope. If there is no damage caused by the impulse voltage, the waveform will be complete and undistorted. The impulse test voltage Recommended by I.E.C. (International Electrotechnical Commission) are given in the table. 1.

TABLE. 1

System Voltage	I.E.C. Impulse Withstand Voltage
11 kV	75 kV
33 kV	170 kV
66 kV	325 kV
132 kV	550 kV

(A) Simulation of 5 stages Equivalent circuit model of impulse voltage Generator for load of 19/33kv Cable capacitance

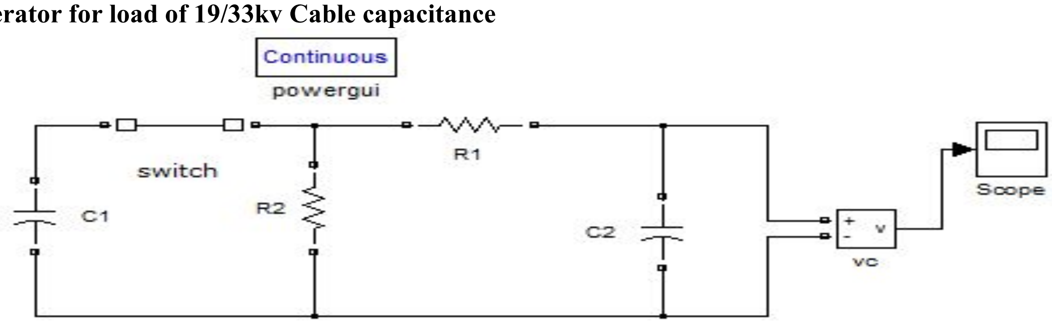

Fig. 1 Simulation Circuit (A)

Here,

V_0 = maximum output voltage = 37×5= 185kv
C_1 = generator capacitance = (0.33/2) × (1/5) = 0.033µf = 33nf
The IEC standard value of capacitance of cable 19/33kv-3×400mm^2= 0.23µf/km
Length of cable = 10 meter
C_2 = the load capacitance for 10m cable = (0.23/1000)×10µf = 2.3nf
R_1 = front resistance
R_2 = tail resistance
C_1/C_2 = (33/2.3) = 14.348

These parameter values has been used in the model and the values of R_1 = 85Ω and R_2 = 2030Ω is obtained to get a standard impulse voltage wave. The simulation view of standard impulse voltage wave is shown in Fig. 2.

Simulation view

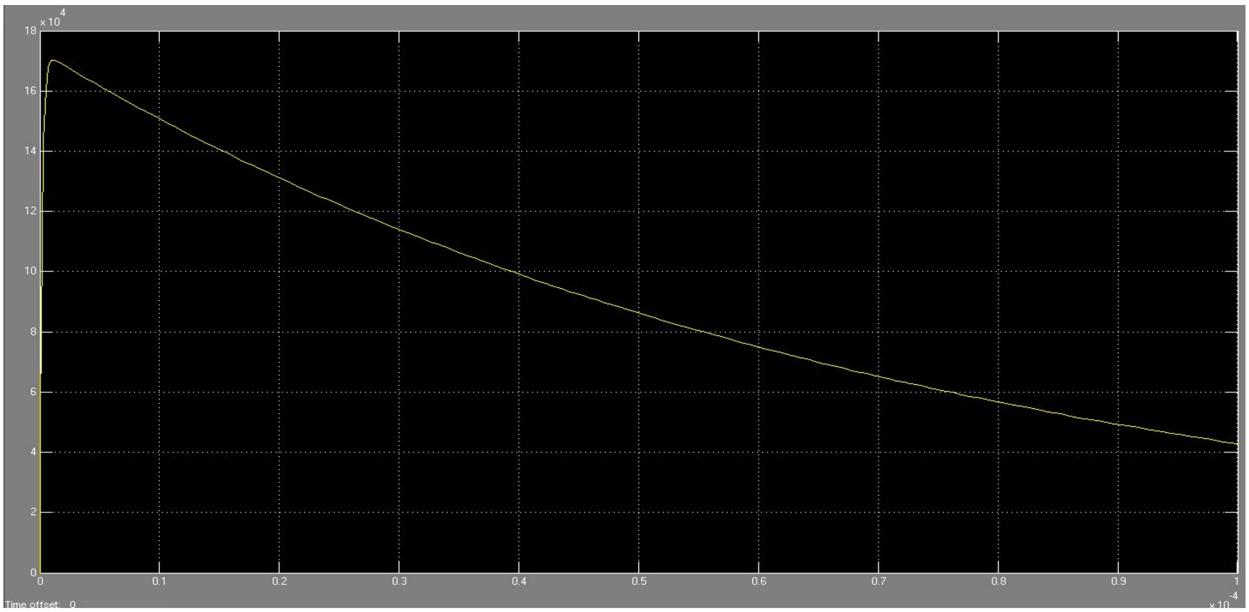

Fig. 2 Simulation with C_1/C_2 = 14.348

Wave front time (T_1) = 1.231µs Wave tail time (T_2) = 50.93µs

The maximum output voltage obtained from simulation = 170.19kv
Here to get a standard impulse voltage wave multiple numbers of simulations has been carried out by varying parameters front resistance (R_1) and tail resistance (R_2).

(B) Marx circuit model of 5 stages impulse voltage generator for load of 19/33k Cable capacitance

Here,
V_0 = maximum output voltage = 37×5= 185kv
Cg = Generator capacitance = (0.33/2) × (1/5) = 0.033µf = 33nf
The IEC standard value of capacitance of cable 19/33kv-3×400 mm^2 = 0.23µf/k.m
Length of cable = 10 meter
C_9 = the load capacitance for 10m cable = (2.3/1000) ×10µf = 2.3nf
R_1 = front resistance
R_2 = tail resistance
C_g/C_9 = (33/2.3) = 14.348

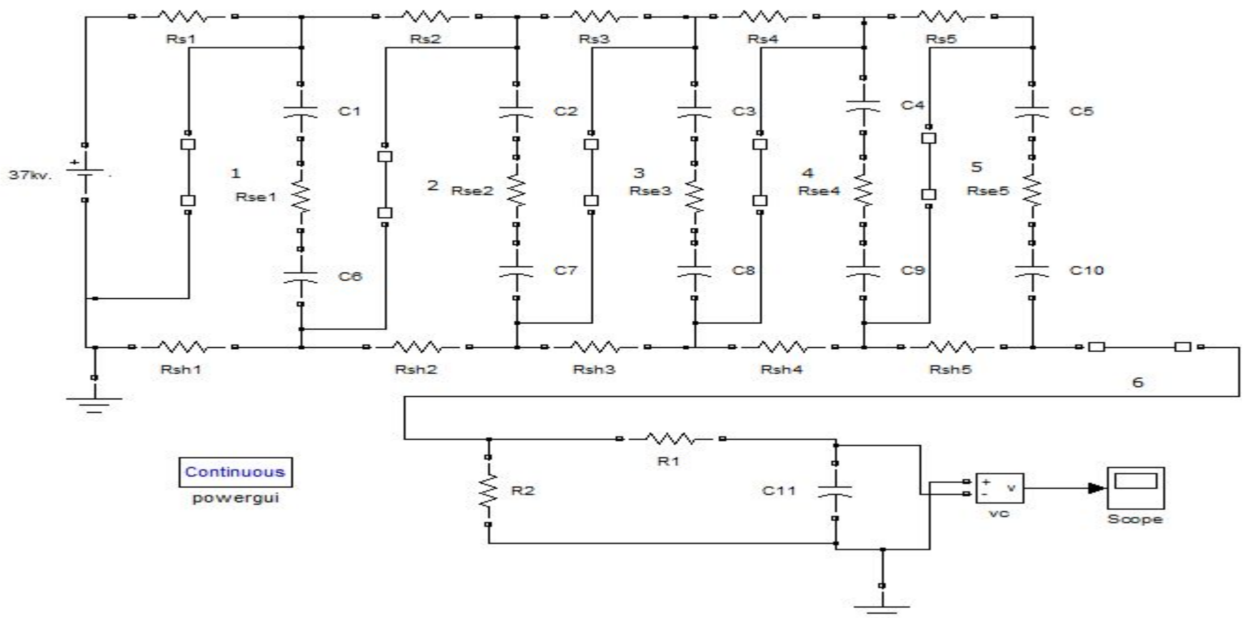

Fig. 3 Marx circuit model (B)

The above parameter values has been used in the model and the values of R_1 = 84Ω and R_2 = 2650Ω is obtained to get a standard impulse voltage wave. The front resistance values obtained from simulation of equivalent circuit model and Marx circuit model are nearly same but tail resistance obtained has been larger in the Marx circuit model compare to the equivalent circuit model to get a standard impulse voltage waveform. The % change in tail resistance (R_2) obtained from Marx circuit model with respect to tail resistance (R_2) obtained from equivalent circuit model is 30.54%. The simulation view of standard impulse voltage wave is shown in Fig. 4.

Simulation view

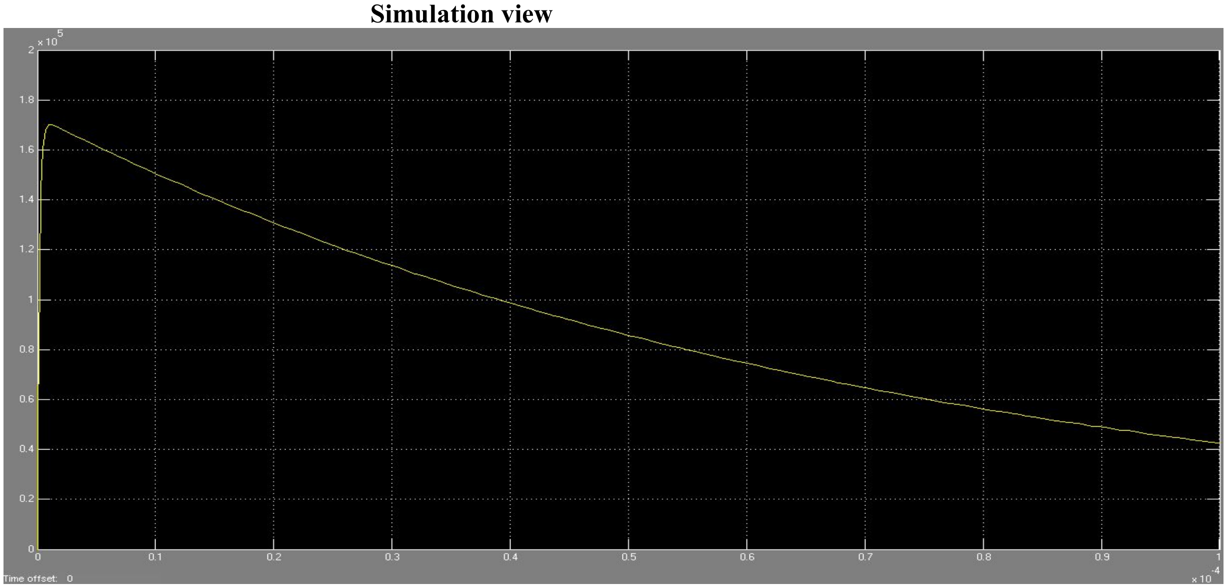

Fig. 4 Simulation with C_g/C_9 = 14.348

Wave front time (T_1) = 1.2157µs Wave tail time (T_2) = 50.535µs

The maximum output voltage obtained from simulation = 170.19kv

(C) Simulation of Marx circuit model of 5 stages impulse voltage generator For load of 19/33kv Cable capacitance with different parameter

TABLE. 2: Variation in R_1 with $R_s = R_{sh}$ =3000Ω, R_2 = 2650Ω

SL NO.	R_1(Ω)	R_2(Ω)	V_0(kv)	T_1(µs)	T_2(µs)
1	50	2650	169.09	0.9233	33.921
2	100	2650	169.72	1.4465	50.780
3	150	2650	168.64	1.6480	51.285
4	200	2650	167.57	2.1955	51.874
5	250	2650	166.50	2.7420	52.405
6	300	2650	165.45	3.2875	53.054
7	350	2650	164.41	3.8320	53.613
8	400	2650	163.38	4.3756	54.167
9	450	2650	162.38	3.6606	54.708
10	500	2650	161.66	4.0645	55.129

TABLE. 3: Variation in R_2 with $R_s = R_{sh}$ =3000Ω, R_1 = 84Ω

SL NO.	R_1(Ω)	R_2(Ω)	V_0(kv)	T_1(µs)	T_2(µs)
1	84	1000	167.80	0.9223	22.93
2	84	2000	169.61	0.9235	40.67
3	84	3000	170.42	1.2160	55.32
4	84	4000	170.84	1.2163	67.47
5	84	5000	171.09	1.2165	78.04
6	84	6000	171.26	1.2167	87.04
7	84	7000	171.38	1.2167	94.64
8	84	8000	171.47	1.2169	101.77
9	84	9000	171.54	1.2170	107.85
10	84	10000	171.60	1.2170	113.20
11	84	11000	171.65	1.2171	118.15
12	84	12000	171.69	1.2171	122.62
13	84	13000	171.72	1.2171	126.64
14	84	14000	171.75	1.2172	130.11
15	84	15000	171.77	1.2172	133.42
16	84	16000	171.79	1.2172	136.55
17	84	17000	171.81	1.2172	139.30
18	84	18000	171.83	1.2172	142.06
19	84	19000	171.84	1.2172	144.63
20	84	20000	171.86	1.2173	146.88

It is observed from Table. 2 that when the front resistance (R_1) increases by keeping other parameters (R_s, R_{sh}, and R_2) constant the corresponding wave front time also increases whereas wave tail time nearly constant with small reduction in output voltage. It is also observed from Table. 3 that when the tail resistance (R_2) increases by keeping other parameters (R_s, R_{sh}, and R_1) constant the corresponding wave tail time also increases whereas wave front time nearly constant with small reduction in output voltage.

(D) Simulation of 3 stages Equivalent circuit model of impulse voltage Generator for load of 6.35/11kv Cable capacitance

Here,
V_0 = maximum output voltage = 27×3= 81kv
C_1 = generator capacitance = (0.33/2) × (1/3) = 0.055µf = 55nf
The IEC standard value of capacitance of cable 6.35/11kv-3×400mm^2= 0.29µf/km
Length of cable = 10 meter
C_2 = the load capacitance for 10m cable = (0.29/1000)×10µf = 2.9nf
R_1 = front resistance

R_2 = tail resistance
$C_1/C_2 = (55/2.9) = 18.965$

These parameter values has been used in the model and the values of $R_1 = 74\Omega$ and $R_2 = 1220\Omega$ is obtained to get a standard impulse voltage wave. When we compared front and tail resistance obtained for 19/33kv cable model and 6.35/11kv cable model it has been observed that whenever the rating of the cable decreases the corresponding front and tail resistance also decrease to get a standard impulse voltage waveform. The simulation view of standard impulse voltage wave for 6.35/11kv cable model is shown in Fig. 5.

Simulation view

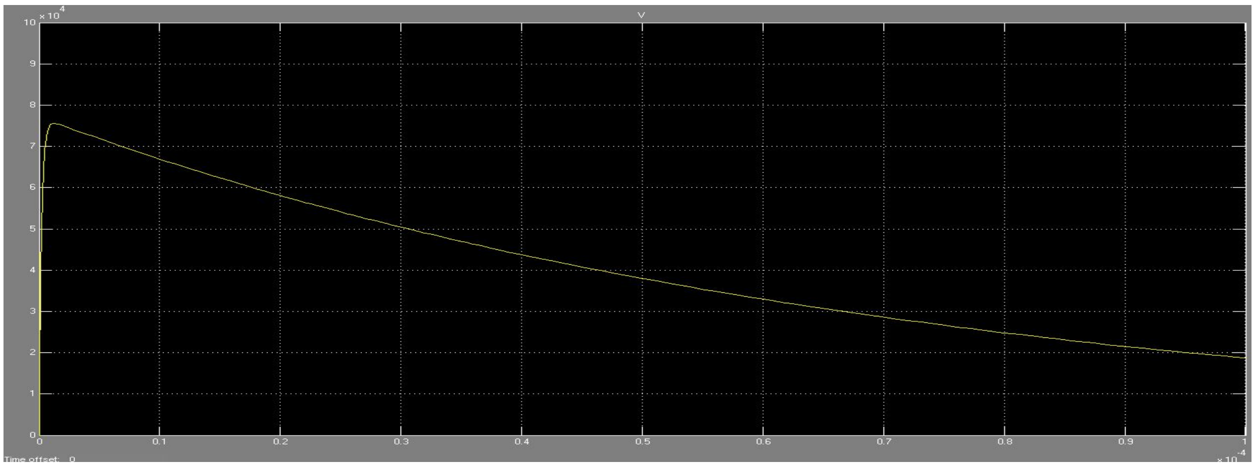

Fig. 5 Simulation with $C_1/C_2 = 18.965$

Wave front time (T_1) = 1.229µs   Wave tail time (T_2) = 50.362µs
The maximum output voltage obtained from simulation = 75.632kv

II. CONCLUSION

It is concluded from the simulation of equivalent circuit model and Marx circuit model that the front resistance values obtained from both simulations are nearly same but tail resistance obtained has been larger in the Marx circuit model compare to the equivalent circuit model to get a standard impulse voltage waveform. The % change in tail resistance (R_2) obtained from Marx circuit model with respect to tail resistance (R_2) obtained from equivalent circuit model is 30.54%.
It is also concluded that for the capacitive load of 19/33kv cable and 6.35/11kv cable to the equivalent circuit model the obtained values of front and tail resistance decreases when the rating of the underground power cable decreases from 19/33kv to 6.35/11kv to get a standard impulse voltage waveform.

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