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Optimization of Cable Length in Transmission Line - Cable Fed G.I.S System

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Abstract: *Transmission line cannot be directly terminated with connection to GIS, hence we use cable for termination of transmission line and connect to GIS , the problem is how much length of cable to be used Short length are generally not preferred and long length of cable will lead to raise in voltage levels because of capacitance . This paper deals with finding the best possible cable length for transmission line termination. EMTP software is used to simulate this system and observe results to decide on the best possible length of the cable used. (Generally we use XLPE cables). 400kv -Transmission line of 100 km is considered and a 400kv XLPE cable is selected for the study. Study on this system is done by giving impulse voltages (both switching and lightning impulse) for the circuit and observing the voltage levels at transmission line end and cable end.*

Keywords–*Cable, GIS, Impulse, Transmission line, Voltage level*

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I. Introduction

Usage of cables to join transmission line and GIS leads to very high voltages when used at greater lengths if we use cables of short lengths then we face huge voltage values due to switching and lightening conditions and reduction in performance, hence there is need to find the optimum length of a cable suitable to join transmission line and GIS

The current project is study about the lengths of cable to be used for connecting a 400kv transmission line and Gas Insulated Substation. Generally XLPE cables are used, but we face many problems due to usage of cables to minimize the problems due to cable usage, this project will provide near possible solution based on observations done by using cables of different lengths and given with two types of impulses, lightning impulse and switching impulse. Observations on the voltages will be one and comparison between voltages at transmission cable junction and cable end will be done and based on that parameter we will find the best possible solution to our problem

Transmission line is generally employed to interconnect the generating stations to load centers and intermediate substations where further electrical operations are performed to maintain a quality of power supply at the load points or customers. But in general transmission lines are not directly connected to the substation if it is GIS (gas insulated substation) because of the travelling waves present in the transmission line. So to backup this situation a cable of certain length is used to inter connect the transmission line and the gas-insulated-substation which will suppress the steepness in the travelling waves due to dominant capacitive nature of the cable because in the whole cross section area 75% of it is insulation which acts as a capacitor. This nature of the cable has disadvantage that under normal operating conditions this capacitance will raise the voltage level at the substation end if the cable length is not confined to a particular value which we have to find in this paper

II. MATERIALS AND METHOD

MATERIALS:

ELECTROMAGNETIC TRANSIENT PROGRAM-EMTP:

Electromagnetic transient program (EMTP) software is employed to study the conditions of the cable and transmission line during the abnormal conditions. EMTP is used for the transient analysis of the electrical equipment’s efficiently without any complexity.

III. METHOD:

BLOCK DIAGRAM:

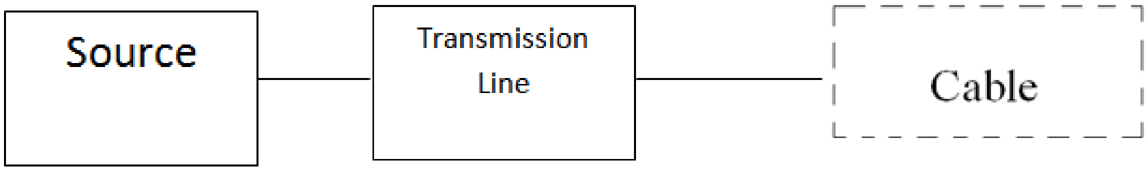

Figure 1:Block Diagram

The analysis of the problem outline is done mainly by constructing a 400KV 100KM long transmission line and a cable of certain length and connecting them to a impulse supply The transmission line we are using in this current project is a 100 km transmission line with 400KV as the transmission voltage. This 100 km is a π network with 10 sections. (i.e.-Each section is of 10 km.)

Transmissionlinesthavetseriestparameterst(resistance,tinductance),tshunttparameterst(leakagetconductance,tchargingtcapacitance)tandttheytaretdistributedtalongtthetentiretline.tAtrigoroustsolutiontwilltinvolvetconsiderationtoftalltparameterstinttheirtdistributedtform.tIt'stverytmuchttimetconsumingtunlesstyoutusetatcomputer.tSotfort50/60tHztpowertlinestapproximationstaretmadettotgettsolutionstrelativelyteasily.Now long transmission line are classified into two types mainly π(pie) network and T-Network[1,2]

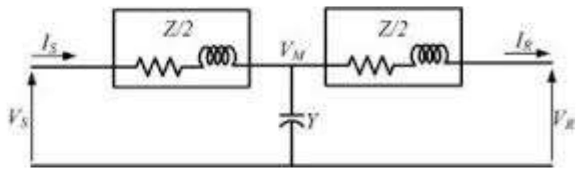

Figure 2: Long transmission line – T network

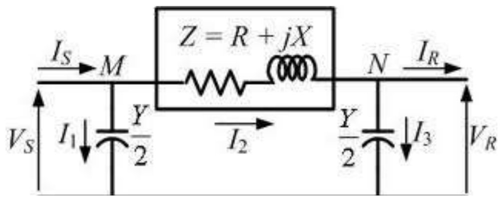

Figure 2: Long transmission line- π networks

Note that for a given data the solution by nominal T and π methods will not give the same result - because of the differing degrees of approximations. However nominal π method is generally recommended and used in modeling. Main reason is that a T representation creates a new node (bus) whereas the π representation does not. This is a clear advantage in power system studies where you have to model many lines

Calculation of R,L,C parameters for 400kv line:

The standard line parameters on 100MVA base line per kilometer are

Resistance (Ω)/km=0.04727

Reactance (Ω)/km=0.33920

Susceptance (µΩ)b/2=1.6821

We know that reactance X=2πfl =0.33920

=0.33920/314

L/km=1.0797mH

SusceptanceXc=2πfc/2=1.62811x10*-6

= 1.62811x10*-6/314.5

C/km =0.010697µF

R = 0.0472 Ω/km

L= 1.04 u H / km

C= 5.356 * 10^-9 F/km

The transmission line we used is a 100 km line divided into ten sections and the parameters of each section will be
Resistance:R Ω /km * 10 = R Ω / 10km
R Ω / km = 0.0472 Ω * 10 = **0.472 Ω**
Inductance:L/km *10 = L/10km
L = 1.04uH * 10 = **10.4 mh/10km**
Capacitance:C /km * 10 = C / 10 km
C. = 5.356 * 10^-9 * 10 = 5.356 * 10^-8 F/10 km
C= **0.05356 micro Farads**

CALCULATIONS OF CABLE PARAMETERS:

The cable parameters are taken from a technical catalog of a cable company; we have considered the values or r, l, c from these values and took surge impedance to be 60 Ω[3].The length of the cable vary in our project as we are to find the optimum length which can be taken for a 400 kv line termination and join GIS , so we took the per km values of components and they are
R = 0.229434 Ω / km
L= 5.0176 mH / km
C = 1.6 * 10^-6 F / km
From the above values we have to calculate the RLC values by multiplying with the length of the cable in km, let's see the values for different cable length.

Cable length (in m)	R	L	C
100	0.02295	0.5015	0.08
200	0.0459	1.003	0.16
300	0.06885	1.5045	0.24
400	0.0918	2.006	0.32
500	0.11475	2.5075	0.4

Table 1:Cable parameters for different lengths

In this project we are introducing two types of faults and trying to study the characteristics of the line joined with cable. We apply two types of impulses in this project

1. Lightening Impulse
2. Switching Impulse

LIGHTNING IMPULSE (1.2/50µs):
Lightening impulse is created by lightning strokes, either direct or indirect strokes, this lightning stroke introduce a very fast transient in the system and we will observe the behavior of the system to these transients.Charecteristics of lightening impulse are as follows[4-6]

α = 14770(attenuation constant) β= 1933000 (phase constant)
Front time= 0.001sec Tail time= 0.002sec

When this impulse is applied to an simple RLC circuit shown below before applying to the transmission line connected to the cable for analyzing the test signal

SWITCHING IMPULSE(250/2500µs):
Switching impulse is seen during operation of crucial switchgear equipment and faults in the system. Switching impulse is different from lightning[7-9].Characteristics of lightening impulse are as follows
α = 347.58(attenuation constant) β= 9615.38 (phase constant)
Front time= 0.001sec Tail time= 0.007sec

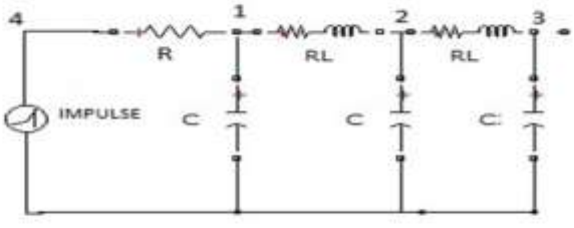

Figure3:RLC circuit for analysing the testing signals

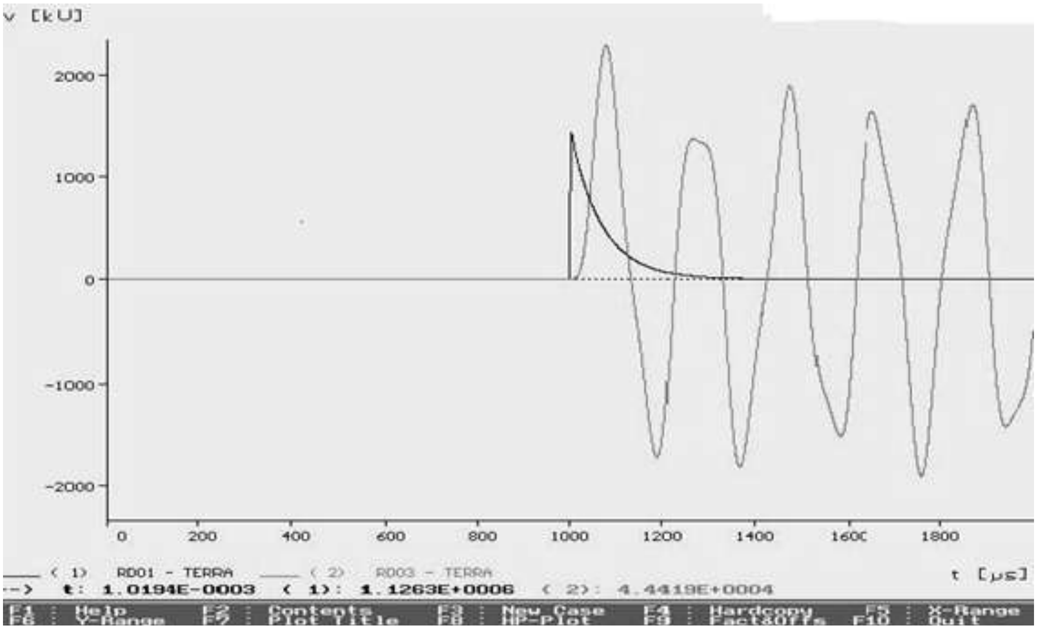

Figure 4: Output plot of an RLC given with lightning impulse

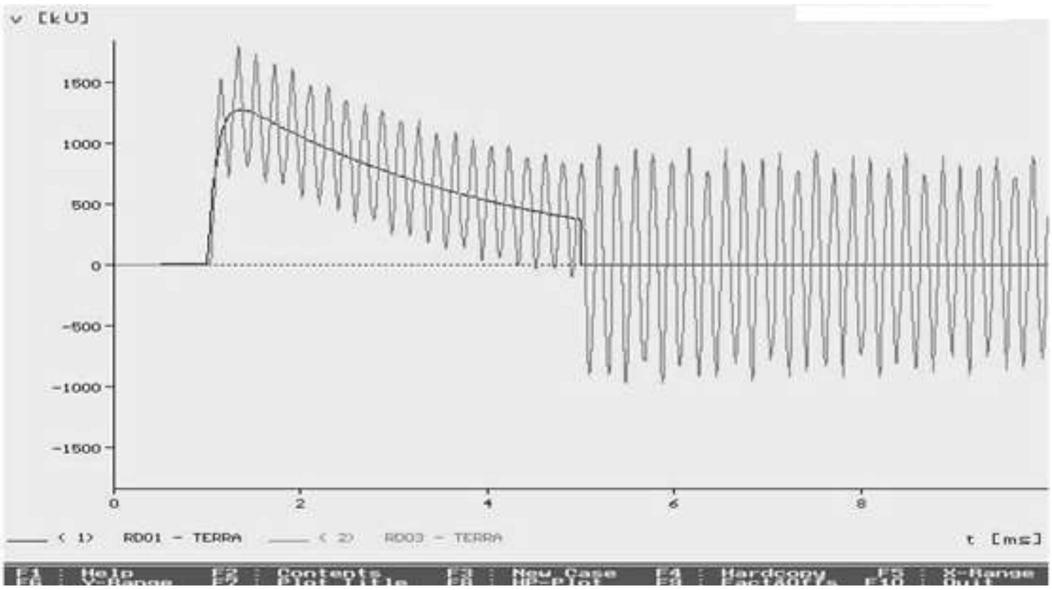

Figure 5: Output plot of an RLC given with switching impulse

The response for the lightening impulse given to RLC circuit is shown in figure 4 and we can observe that for a given 1500KV impulse given nearly 2000KV is appearing at the end side so clearly rise in voltage is appearing at the load end so transmission line can’t be terminated directly so a cable is employed for interconnection The response for the switchingimpulse on an rlc network is shown in figure5 , the plot is in between voltage (on y axis) vs. time (on x axis) this simulation is done to observe the properties of the impulse given, for 1500kv impulse given we can see voltages up to 2000 kv and gradually decrease, and later even the impulse is stopped, we still have same voltage fluctuations in the circuit, showing the danger it pose to the system.[10]

Circuit Diagram:

The circuit diagram shown below has a transmission line of 100KM length divided into ten sections each of 10KM length which is then connected to a cable of length 2KM length divided into ten sections each of 200meters and it is to be noted that every time 200meter cable is added and performance of the system is studied the addition of cable length is confined to 2000metr length

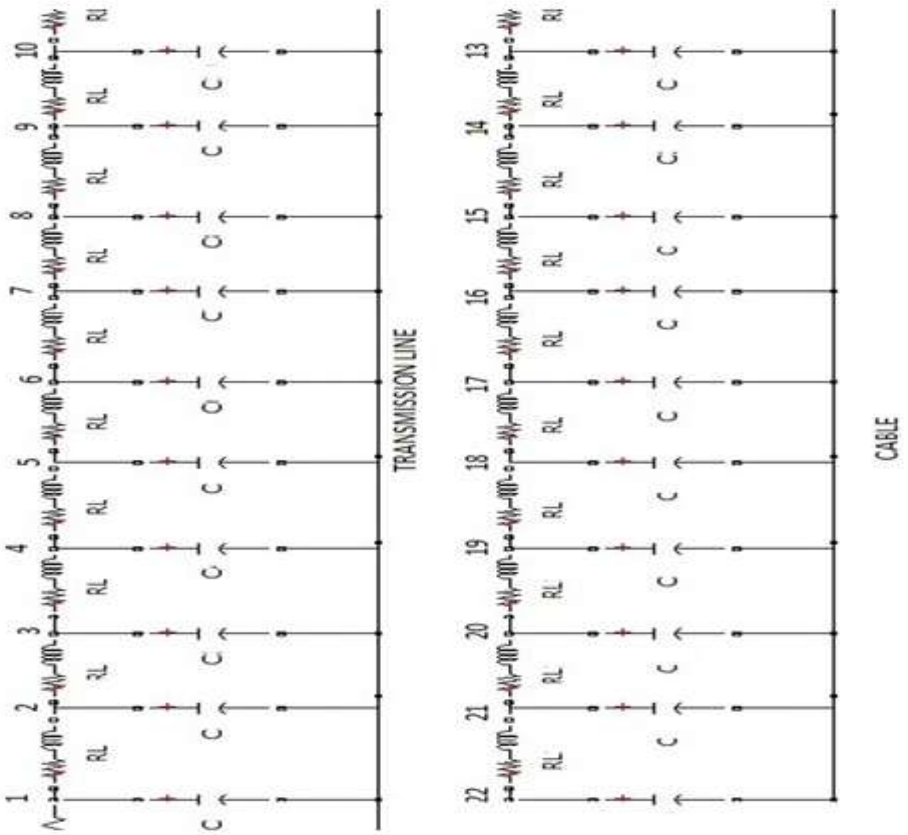

Figure 6:circuit diagram with transmission line of 100km and cable of 2km

Figure 7: Output of transmission line with 400m cable fed with lightning impulse

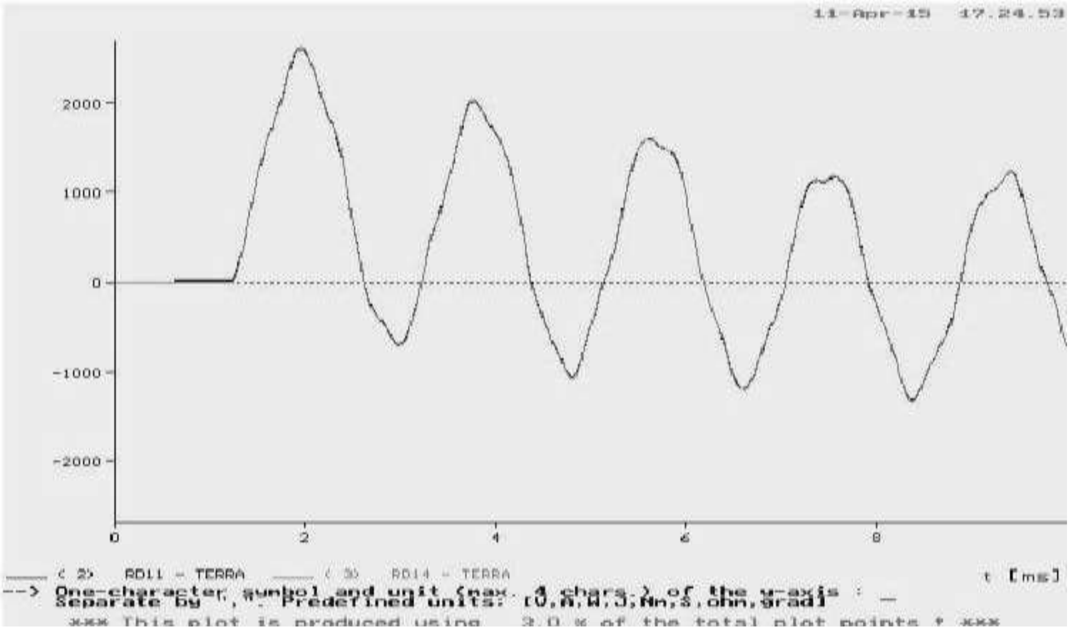

Figure 8: Output of transmission line with 400m cable fed with switching impulse

Table 1: Outputs of transmission line(t/m) with various cable lengths fed with lightning impulse of 1500KV

cable length(m)	t/m end(junction) (volts)	cable end voltage(volts)
200	748060.00	796100.00
400	492790.00	512230.00
600	233360.00	453710.00
800	225200.00	444120.00
1000	224650.00	441850.00
1200	224620.00	440280.00
1400	224620.00	438830.00
1600	224620.00	437340.00
1800	224620.00	435900.00
2000	224620.00	434450.00

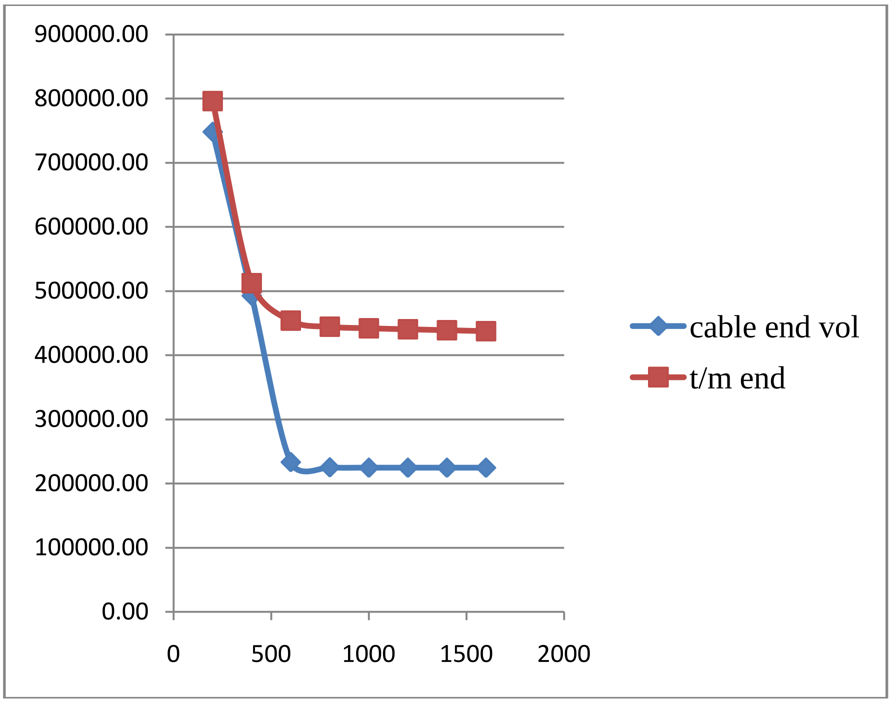

Figure 9: Plot of voltage at transmission cable junction v/s Voltage at end of cable for lightening impulse

Table 2:Outputs of transmission line with various cable lengths fed with switching impulse of 1500KV

cable length(m)	cable end voltage(volts)	t/m end voltage(volts)
200	2738000.00	2756400.00
400	2625100.00	2600300.00
600	2467400.00	2442900.00
800	2389800.00	2330000.00
1000	2386900.00	2294400.00
1200	2375100.00	2260200.00
1400	2332800.00	2221300.00
1600	2233100.00	1992000.00
1800	2226700.00	1974100.00
2000	2202300.00	1944000.00

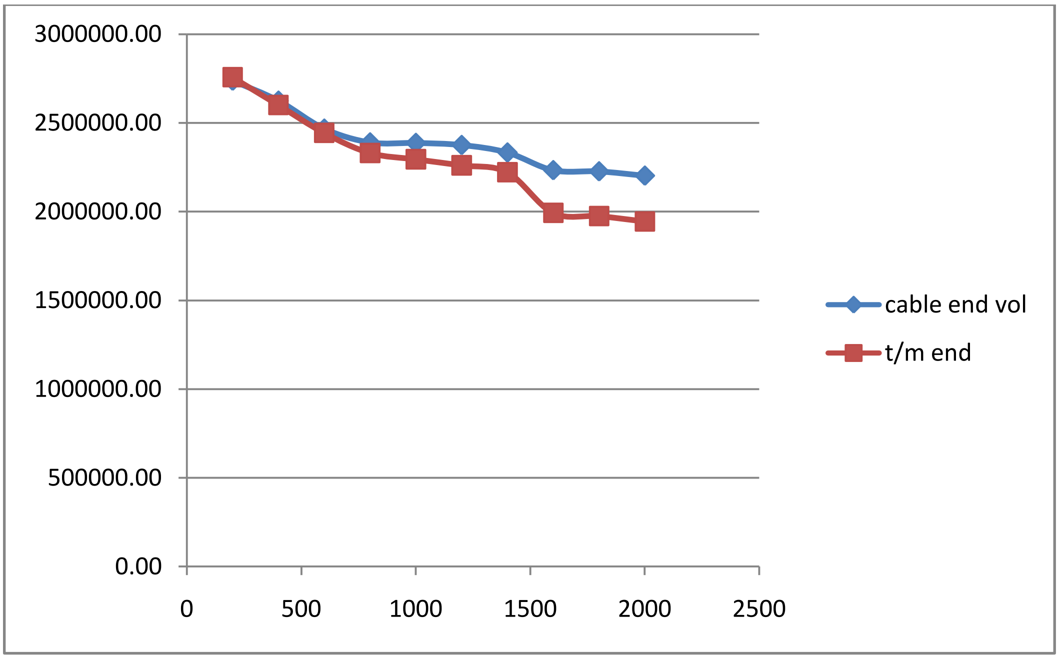

Figure 9: Plot of voltage at transmission cable junction v/s Voltage at end of cable for switching impulse

IV. Conclusion

From the whole anlysis we can clearly see that there is poor voltage regulation for cable lengths above 600 and we also observe that as the length increases there is a reduction in the value of voltage, this is due towhen impulse is given to the transmission line ,it is only for very short period of time but line gets charged and we can see current travels along line even after impulse effect is over, but slowly damping elements come into picture to reduce these transients. As length of the transmission line increase damping also increases. Hence we can see reduction in peak voltages, but as length of cable increase along with damping capacitive nature also increase and hence there is difference between voltages at transmission line and cable junction and voltage at cable end. There is high voltage seen for cables with lengths below 400 meters, hence in this case 600 meters seems to be good length in the case of lightning and switching impulse

Based on these factors and simulations we have observed that, cable of lengths between 400-800 meters seems to perform well. In simulation of cable with 400kv supply , there was about 20 times raise in voltage difference between sending and receiving end (i.e.- 500m cable, raise in voltage is 40 v , while for 2000m cable has raise in voltage of about 816 v). This shows the importance of cable length. Based on the values plotted for voltage v/s cable length with lightning impulse and switching impulse, cables with lengths from 600 meters simultaneously showed better results compared to other lengths .hence length of 600 meters can be considered as optimum value

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