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EMTP-analysis of Sheath Circulating Current on Power Cables

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1. Introduction

In order to meet the increasing demand for electric power cables of two or more circuits have been installed in ducts in parallel for several kilometer in the same route. It, however, has not been known generally that the sheath circulating current is generated in a system where a large number of cables are laid on the same route.

Therefore, the sheath circulating currents were measured for this study in an actual power cables, and were analyzed by a generalized circuit analysis program EMTP(Electromagnetic Transient Program) for comparison with the measured values, It is proved that sheath circulating currents generated in unbalanced horizontal arrangement and length can be analyzed well by EMTP.

2. System description and simulation

The power cable system model consists of a 154kV single terminal source and an XLPE cable of 2,000SQ cross-sectional area, 3.53km length, and 10 cable sections in duct. The cable constant was calculated using the CABLE CONSTANTS program(EMTP sub-routine program).
The cable arrangements of two circuits of routes A and B are shown in Fig. 1 and Table 1.

In order to minimize the steady stage sheath loss due to circulating current, sheaths are bonded at junctions #1,#2, #4,#5,#7,#8 and #9 respectively. The sheaths are directly grounded at junctions #3, #6, #9.5 and cable terminals.

Fig 1. shows unbalanced cable arrangement(from #1 to #3) and length(from #7 to #9.5) of cross-bond minor sector.

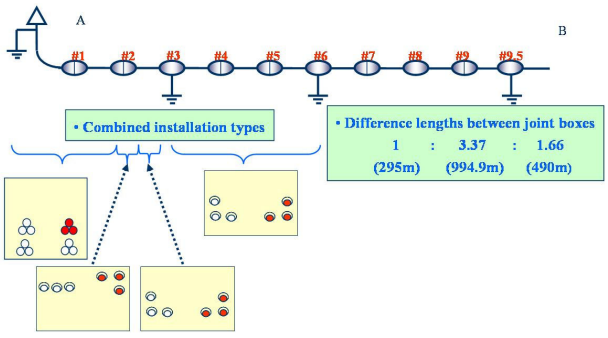

Fig. 1. Unbalanced cable arrangement and length of cross-bond minor sector

Table 1. Length and grounding method for underground cable

Section	A	J/B #1	J/B #2	J/B #3	J/B #4	J/B #5	J/B #6	J/B #7	J/B #8	J/B #9	J/B #9.5
Type	EBG	SJ	IJ	IJ	NJ	IJ	IJ	NJ	IJ	IJ	NJ
Earth Mthod	1 [Ω]	Cross bond	Cross bond	1 [Ω]	Cross bond	Cross bond	1 [Ω]	Cross bond	-	Cross bond	Cross bond
Length [m]		298.5	250	254.7	188	439.8	322	295.1	485.3	508	489

Therefore, the sheath circulating currents were measured for this study in an actual power system of underground cables, and were analyzed by a generalized circuit analysis program EMTP for comparison with the measured values. It is proved that sheath circulating currents generated in unbalanced horizontal arrangement and length can be analyzed well by EMTP.

Table 2. shows measurment results of the sheath circulating current and calculated results by the EMTP. As shown in Table 2, the average error between measured and calculated values is about 12%

Table 2. Comparison between measured and calculated values

Measured Point		Sheath Circulating Current[A]						
		A		B		C		Error Rate (%)
Joint Box	Cable Num.	Field Test Result	Calcu-lated Result	Field Test Result	Calcu-lated Result	Field Test Result	Calcu-lated Result	
A	1	175	179.3	173	181.8	148	141.2	1.17
	2	170	173.5	132	157.9	107	164.4	25.0
J/B #1	1	175.8	173.7	175.9	186.7	150.3	140.9	0.13
	2	169	173.6	128.2	172.9	105.7	164.4	21.3
J/B #2	1	153.9	141.0	182.2	178.6	178.7	182.2	2.8
	2	106.7	164.5	173	179	132.1	153.7	26.7
J/B #3	1	308.9	314.8	266.5	220.3	327.3	324.7	4.63
	2	228	247.5	199.4	249.8	171.4	265.3	23.9
J/B #4	1	109.6	118.9	91	92.9	87.4	143.2	20.4
	2	98.1	82.20	82	95.4	90.3	85.87	2.4
J/B #5	1	114.6	139.1	96	119	94.4	93.08	3.4
	2	102.1	81.14	86	82.38	94.3	95.93	7.5
J/B #6	1	278	190.8	293	306.6	294	256.5	13.3
	2	216	202.4	217	151.1	241	189.2	20.3
J/B #7	1	130	96.12	161	198.6	176	184.7	3
	2	151	120.1	133	133.7	122	107.8	9.8
J/B #9	1	172	197.8	221	184.4	183	95.52	15.2
	2	140	133.6	157	107.7	135	120.0	16.8

3. Reduction method of sheath circulating current

To reduce the sheath current, the improved arrangements of cable were made in two cases : case(a) same arrangement of cable from A to #3, and case (b) balanced length of cable from #6 to #9.5 (same length of each minor section at 595m).

As a result of improvement, the sheath current is reduced about 85%(maximum 95.78%). It means that the unbalance ratio of cable arrangement or cross-bonding length causes a significant effect on the magnitude of the sheath current.

Table 3 shows results of sheath circulating current according to improved cable arrangement.

Table. 3. The results of sheath circulating current comparison

Measured Point		Sheath circulating current in the ratio of load one[A]		Sheath circulating current according to modification(%)
Joint Box	Cable Num.	Before modification	After modification	
A	1	34.7	0.02	94.4
	2	28.5	0.04	87.2

J/B #1	1	34.7	0.02	94.4
	2	29.6	0.01	98.5
J/B #2	1	35.8	0.02	94.6
	2	28.4	0.04	86.9
J/B #3	1	49.5	18	63.6
	2	52.8	23.9	53.7
J/B #6	1	37.8	16.4	56.7
	2	40.7	18.9	53.5
J/B #7	1	24.0	0.01	96.2
	2	29.3	0.01	97.6
J/B #9	1	21.5	0.10	95.8
	2	29.3	0.01	97.5

But practically, changing the whole arrange of cable which is already constructed is impossible. So this paper suggests that the practical reduction method for installed systems can be applied. The method is an installation of restrain-unit of sheath circulating current at the cross-bond lead cable of insulated joint box where sheath circulating current rises in the section.

As shoun in Table 4, sheath circulating current decrease fairly according to increased impedance values of restrain-unit.

Table 4. Sheath circulating current depending on impedance value

Measured Point		Sheath circulating current[A]					
Joint Box	T / L	Without impedance			With impedance		
					0.1 [Ω]	0.5 [Ω]	1 [Ω]
		A	B	C	A	A	A
A EBG	1	179.3	181.8.	141.2	92.7	30.8	16.9
	2	173.4	157.9	164.4	89.3	31.1	15.9
J/B #1	1	173.7	186.7	140.9	92.6	30.7	16.8
	2	173.6	172.9	164.4	89.2	30.9	17.3
J/B #2	1	141.0	178.6	182.2	81.7	26.2	14.3
	2	164.5	179	153.7	64.5	21.9	9.8
J/B #3	1	314.8	220.3	324.7	144.8	53.1	27.6
	2	247.5	249.8	265.3	168.5	61.2	34.2
J/B #6	1	190.8	306.5	256.5	53.3	21.9	11.3
	2	202.4	151.0	189.2	91.2	47.5	23.2
J/B #7	1	96.1	198.0	184.7	87.2	42.6	26.5
	2	120.1	133.7	107.8	125.8	66.5	43.4
J/B #9	1	197.8	184.4	95.5	93.9	46.3	25.5
	2	133.6	107.7	120	118.5	53.1	30.1
Sheath circulating current reduction rate(%)					41.2	75.6	86.2

As seen in table 3, The average effect of sheath circulating current is about 41.3% when applying restrain-unit of 0.1Ω, and 76.02% when 0.5Ω. Moreover the maximum decrease effect of sheath circulating current is 85.7% when 1Ω

4. Conclusion

This paper proves the accuracies of simulation through comparing measured value of sheath circulating current and simulated results from modeling a practical system. And then it proposes the reduction methods of sheath circulating current. And the sheath circulating current restrain-unit is also applied for practical system using EMTP. This paper can be summarized as followed.

(1) Imbalance of cable section distance increases, sheath circulating current increases rapidly.
(2) Sheath circulating current passes to load current provision 50% by imbalance of cable arrangement and cable distance unbalance of cross bond section. Sheath circulating current could be greatly reduced by symmetrical configuration of the cables.
(3) Sheath circulating current reduction equipment shows that sheath circulating current is critically reduced.

References

(1) KEPRI, “A study on the calculation method of impedance and allow- able current for underground cables”, Korea Electric Power Research Institute, 1996
(2) Turan Gonen, “Electric Power Transmission System Engineering Analysis and Design”, 1988
(3) B. Gustavsen, J. Sletbak, “Transient Sheath Overvoltage in Armoured Power Cable”, IEEE Trans. Power Delivery, Vol. 11, No. 3, PP. 1594-1600, July