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High-Speed and High-Resistance-Tolerance Fault Component Ground Distance Relay for UHV Double-Circuit Transmission Line

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Abstract: UHV AC double-circuit transmission line is of its distinct characteristics of distributed parameters, as a result of large distributed capacitance and long transmission distance. The traditional distance protection has inherent defect when used in UHV double-circuit transmission. According to the distributed parameter model and six sequence component, This paper analyzes and deduces a novel calculation formula of single phase ground distance protection for parallel transmission lines and uses it in fault component distance relay. To improve its resistance tolerance and prevent the relay from “in-phase” problem caused by high fault resistance, we propose a novel type relay with high-speed and high-resistance-tolerance characteristics and its concrete implementation scheme. The scheme can ensure operating speed for low-resistance faults near the start of the protected zone and correct action for high-resistance faults. Simulation has confirmed that the protection scheme is security with high sensitivity, high speed and great capability against fault resistance.

Key words: UHV parallel transmission line, six sequence component; distributed parameters, fault component distance relay

INTRODUCTION

Fault component distance relay is unaffected from the normal load, the system shocks and the two-phase operation. Its outstanding advantages are simple, reliable safe and snap action, which has been widely studied and applied and even as a kind of main protection for UHV transmission line (Barabanov, 2001; Liu *et al*., 2002). The power frequency variation distance relay of which react compensation voltage amplitude variation, which in the case of ensuring security, have a greater resistant to transition resistance capability than which react compensation voltage phase mutation relays and its operating criteria is easily achieved by a half weeks integral (Sui *et al*., 1995). However, the physical meaning of traditional fault component ground relay is not clear when applied to UHV double lines and it is influenced by the distributed capacitance and mutual inductance between the lines, which leads to large deviations; On the other hand, increasing resistant transition resistance capability of fault component single-phase ground distance relay is an important research content (Suonan *et al*., 2003; Xu, 2002), however, when the capability enhance to appear the "same phase problems", in the "in-phase region", the criterion of fault component relays will be completely reversed.

This article based on distributed parameter model and six sequence component method, theoretical analysing and deducing a new calculation expression of UHV double circuit single-phase distance element measured impedance and applied to the fault component distance relay. In reference to the fast distance protection, to improve the resistant transition resistance capacity of such relay and avoid the uncorrected action of the "same phase problem" caused by transition resistance, we propose a fast-resistant high impedance fault component single-phase ground distance relay and its specific implementation program, which not only ensures fast movement at low transition resistance, but also provides with the correct operation in high transition resistance. The simulation results show that the protection scheme has high sensitivity, action fast, resistant transition resistance ability extremely and has a high practical value.

Fundamental principle

Fault component distance relay: The commonoperating criteria of magnitude comparative criterion fault component distance relay is (Barabanov, 2001):

$$|\dot{U}' - K\dot{U}_{|0|}'| \geq |K\dot{U}_{|0|}'|$$

Distribution parameter characteristics and phase sequence transformation: UHV transmission lines need to consider the distributed parameter characteristics of lines. The simple schematic diagram of each variable among

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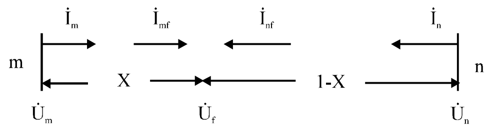

Fig. 1: Diagram of line voltages and currents

Table 1: Relation between six sequence component parameters and phase parameters

The sequence	Same phase zero sequence	Reverse phase zero sequence	Positive and negative sequence
Parameter	T_0	F_0	$T_1 = T_2 = F_1 = F_2$
Impedance	$Z_s+2Z_m+3Z_m'$	$Z_s+2Z_m-3Z_m'$	Z_s-Z_m
Admittance	$Y_s+2Y_m+3Y_m'$	$Y_s+2Y_m-3Y_m'$	Y_s-Y_m

Z_s is self-impedance; Z_m is interphase mutual impedance; Z_m' is line to line mutual impedance; Y_s is self-admittance; Y_m is interphase mutual admittance; Y_m' is line to line mutual admittance

lines shown in Fig. 1, among which the voltage and current indicate the Independent mold fault component, rather than specific phases or lines. It can be obtained initial terminal voltage, current mode vectors and the voltage in fault, the current mode vectors satisfy equation (He *et al*., 2002).

$$\begin{cases} \dot{U}_m = \dot{U}_f \text{ch}\gamma x + \dot{I}_{mf} Z_c \text{sh}\gamma x \\ \dot{I}_m = \dot{I}_{mf} \text{ch}\gamma x + \dfrac{\dot{U}_f}{Z_c} \text{sh}\gamma x \end{cases}$$

where, Z is the impedance parameter of the line-mode fault component; Y is the admittance parameter of line-mode fault component.

For the double circuit line of the uniform transposition, which is using six-sequence fault component analysis, the electrical quantities of lines and sagami conversion relationship of parameters is (Li *et al*., 2007):

$$\dot{U}_{TF} = M^{-1}\dot{U}_{??} \quad \dot{I}_{TF} = M^{-1}\dot{I}_{??}$$

$$Z_{TF} = M^{-1}ZM \quad Y_{TF} = M^{-1}YM$$

In above formula: $\dot{U}_{TF} = [\dot{U}_{T0}, \dot{U}_{F0}, \dot{U}_{T1}, \dot{U}_{F1}, \dot{U}_{T2}, \dot{U}_{F2}]^T$ are voltage six-sequence component of the same phase, reverse phase, zero sequence, positive sequence and negative sequence; $\dot{I}_{TF} = [\dot{I}_{T0}, \dot{I}_{F0}, \dot{I}_{T1}, \dot{I}_{F1}, \dot{I}_{T2}, \dot{I}_{F2}]^T$; $\dot{U}_{I\,II} = [\dot{U}_{IA}, \dot{U}_{IB}, \dot{U}_{IB}, \dot{U}_{1C}, \dot{U}_{IIA}, \dot{U}_{IIB}, \dot{U}_{IIC}]^T$ are double circuit line voltage vectors; $\dot{I}_{I\,II} = [\dot{I}_{IA}, \dot{I}_{IB}, \dot{I}_{IB}, \dot{I}_{1C}, \dot{I}_{IIA}, \dot{I}_{IIB}, \dot{I}_{IIC}]^T$; Z, Z_{TF} and Y, Y_{TF} are respectively phase impedance matrix, mode impedance matrix and phase admittance matrix, mode admittance matrix of lines.

Similar to the three-phase network, after a six-sequence phase mode conversion, we take the double circuit line of presenting mutual inductance between phases and lines decouple into independent sequences, each modulus parameters shown in Table 1.

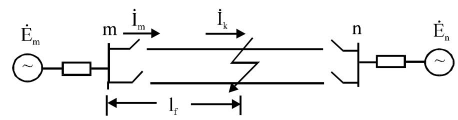

Fig. 2: Simplified system of double circuit transmission line on a same tower

UHV AC double-circuit line fault component with the same tower single-phase ground distance relay.

Impedance measurements of impedance element with the same pole UHV single phase ground double-circuit line: Two-terminal power supplied with the same tower double-circuit transmission line fault schematic diagram shown in Fig. 2.

In Fig. 2, double circuit transmission line transpose uniformly, distance protection install on the side of *m*, the fault happen at the point of k. $\dot{I}_m$ is defined as the first terminal of the current, $\dot{I}_k$ is the m-side current of flowing into the fault point, l_f is the fault distance.

When double circuit transmission line occur ground fault, we take the A phase ground fault for example, so $\dot{U}_{kA} = \dot{U}_{kTA1}+\dot{U}_{kTA2}+\dot{U}_{kTA0}+\dot{U}_{kFA1}+\dot{U}_{kFA2}+\dot{U}_{kFA0} = 0$. We suppose $\gamma_{T1} = \gamma_{T2} = \gamma_{F1} = \gamma_{F2}$, $z_{Tc1} = z_{Tc2} = z_{Fc1} = z_{Fc2}$, according to formula(He et al., 2002), (Li et al., 2007), we can get (Liu, 2005):

$$z_m = \frac{\dot{U}_{mIA} + K_{Tu}\dot{U}_{mTA0} + K_{Fu}\dot{U}_{mFA0}}{\dot{I}_{mIA} + K_{Ti}\dot{I}_{mTA0} + K_{Fi}\dot{I}_{mFA0}} = Z_{cT1}\text{th}\gamma_{T1}l_f$$

$$K_{Xi} = \frac{Z_{cX0}\text{sh}\gamma_{X0}l_f - Z_{cT1}\text{sh}\gamma_{T1}l_f}{Z_{cT1}\text{sh}\gamma_{T1}l_f} \quad K_{Xu} = \frac{\text{ch}\gamma_{X0}l_f - \text{ch}\gamma_{T1}l_f}{\text{ch}\gamma_{T1}l_f}$$

The relationship of measure impedance of ground impedance represented by formula (Liu, 2005) and fault distance is hyperbolic tangent function. Take 750kV double circuit line for example, K_{Xu}, K_{Xi} (X = T or F)change with the fault distance shown in Fig. 3, measure impedance changes with the fault distance shown in Fig. 4.

Therefore, when UHV double lines with the same pole occurs single-phase ground fault, there is hyperbolic tangent function relationship between measure impedance and fault distance. Compared with conventional compensation coefficient based on centralize parameters, K_{Xu} and K_{Xi} (X = T or F) is no longer constants, which change with the fault distance.

UHV double-circuit lines fault component with the same pole single-phase ground relay: UHV lines have large distribute capacitance, in order to eliminate the impact of distribute capacitance on the fault component relay, the

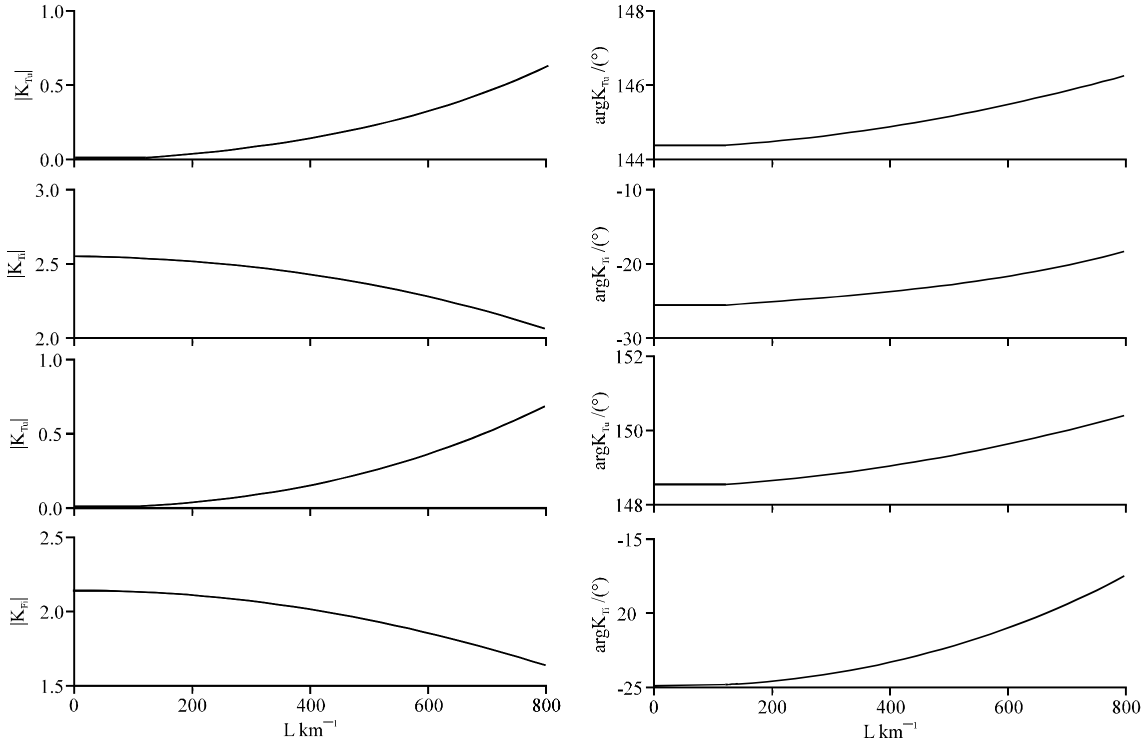

Fig. 3: Variation of KXu and KXi with fault distance

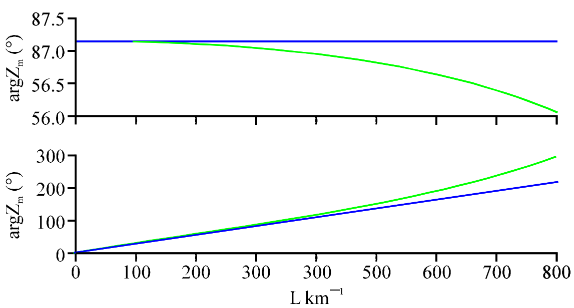

Fig. 4: Relation between measured impedance and fault distance (linear function and hyperbolic function)

offset voltage before and after fault in action criterion (Barabanov, 2001) must be based on distribute parameter model.

According to formula (Barabanov, 2001; He *et al*., 2002; Liu, 2005), we get (Liu *et al*., 2002):

$$|\dot{U}'_{IA} - \frac{\dot{U}_{|0|}'}{ch\gamma_{T1}l_Y}| \geq |\frac{\dot{U}_{|0|}'}{ch\gamma_{T1}l_Y}|$$

From the formula (Liu *et al*., 2002), we know that the traditional frequency variation distance relay exist in principle defects when it apply to UHV double lines. Take the 750 kV typical line parameters for example, the Fig. 5 shows us that $ch\gamma_{T1}l_Y$ changes with line length, according to the figure, $ch\gamma_{T1}l_Y$ phase angle is very small, which can

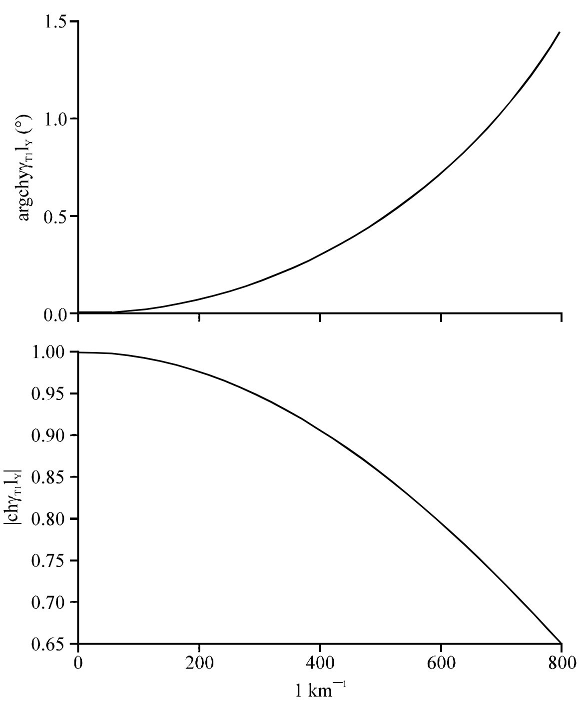

Fig. 5: Variation of ch T1lY with the length of transmission line

be treated as a real number. Because of $ch\gamma_{T1}l_Y<1$, compared with the traditional frequency variation distance relay, its action range become reduce further and its capability of resistant transition resistan become weakened further.

Quick-resistant high impedance fault component relay and its implementation scheme: In UHV distance protection, fault component reactance relay has highly transition resistance resistance, under the premise without considering the system impedance and line impedance, presenting an ideal reactance characteristic, which has very practical value. In formula (Barabanov, 2001) when K = 0.5, we obtain the action criterion, which is (Sui *et al.*, 1995):

$$|\dot{U}' - 0.5\dot{U}_{|0|}'| \geq |0.5\dot{U}_{|0|}'|$$

Fault component relay have advantages with not being affected by transition resistance and stable scope of protection. However, it also has its shortcomings, as shown in Fig. 6, when a fault occurs inside the area, namely the point F falls between bus N and set point Y, the fault point compensation voltage will fall in arc OHF, the greater the transition resistance, the closer its location to the point F. If the transition resistance is too large, the voltage vector after fault will fall in arc HF, as shown in the point F_2. For F_2, it is ?YY_2O > ?FF_2O = 90° which are not satisfied with the criterion of fault component reactance relay; Similarly, when the fault occurs outside the area, it meets criterion (Liu *et al.*, 2002). So when the fault point voltage vector falls in HF, reactance relay criterion will be completely reverse. This situation is called the "same phase problem", H is called "same phase point".

In Fig. 6, $\dot{E}_M$, $\dot{E}_N$ are respectively the sending end and receiving end of the power, the voltage of the fault point F changes with the locus of transition resistance, so the "same phase problem" mainly appear in the receiving end. Take the receiving end for example, observing Fig. 6,we can obtain ?YY_1S_1 = ?FF_1S_1>90° before the "same phase point" and ?YY_2S = ?FF_2S<90° after the "same phase point". We take 1.3 as the reliability factor in this paper, it can be obtained the criterion for the new action (Suonan *et al.*, 2003):

$$\{(|\dot{U}' - 0.5\dot{U}_{|0|}'| > |0.65\dot{U}_{|0|}'|) \cap (-90° < \arg\frac{\dot{U}' - \dot{U}_N}{\dot{U}' - \dot{U}_{|0|}'} < 90°)\}$$

This criterion, based on fault component reactance relay, take fully advantage of reactance relay, which has

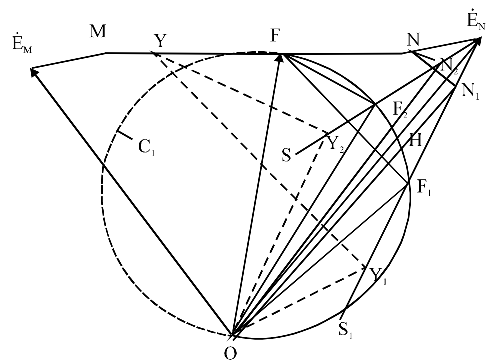

Fig. 6: Voltage phasor diagram for a internal fault with differential fault resistance in a two-source system

strong ability of withstanding transition resistance and stable protection range. In order to ensure the stability of the scope of protection, we take Fourier algorithm; Furthermore, after fault beginning, only when the data window data is the failure data, the result will be a little accurate. So action speed of the criterion is slow, which can not take a kind of fast protection. It is disadvantage to the proximal of UHV, especially protect export occurs metallic single-phase short circuit or low resistance single-phase short circuit.

In order to achieve proximal metallic lines or the fast action of low resistance ground fault, we may have formula (Liu *et al.*, 2002) constitute the criterion 1.

Formula (Suonan *et al.*, 2003) constitute the criterion 2, in order to get the protection scope of stability in criterion 2, we use a low-pass digital filter to remove the high frequency components which is due to stray capacitance.

Criterion 1 and 2 use the different algorithm, the two criterions complement with each other in order to achieve fault component relay fast action and the unity of resistant transition resistance capability.

Simulation verification: In order to verify the accuracy of this algorithm, we use EMTP obtaining simulation data and use MATLAB for algorithm verification, the simulation verification model is 750 kV high voltage transmission lines for the 600 km long shown in Fig. 2, the system parameters refer to northwest 750kV system.

The system parameters of M side: Z_{ms0} = j70.122Ω, Z_{ms1} = j65.999Ω; The system parameters of N side: Z_{ns0} = j61.899Ω, Z_{ns1} = j42.000Ω; Equivalent power line ends the phase angle difference is 30°. Double circuit long line parameters with the same pole are as follows: γ_1 = 0.013326Ω/km, x_1 = 0.266069Ω/km, c_1 = 0.0138776μF/km; γ_0 = 0.307915Ω/km, x_0 = 0.814868Ω/km, c_0 = 0.00977857μF/km; γ_m = 0.01Ω/km, x_m = 0.0157Ω/km, c_m = 3.33×10^{-4} μF/km.

Table 2: Simulation results of power frequency variation distance relay for single phase-to-earth fault (AG)

Sample points	At 80%	At 85%	At 90%	$\dot{U}_{\|0\|}'$	$\dot{U}_{\|0\|}''$
1	①	527750	499140	473690	441990
	②	556760	518830	495860	518260
2	①	526980	498970	473020	441990
	②	556750	518690	492830	518270
3	①	527350	499010	473560	441950
	②	556980	519300	494520	518290
4	①	527670	499030	472120	441970
	②	557020	518970	495560	518270

Simulation obtain the necessary electrical quantities with 48 points sampling rate per week and using full-wave fourier algorithm filtering for the amount of the desired frequency. Tuning range is the line length of 85%, so the value of zero sequence voltage and current compensation coefficient K_{Xu}, K_{Xi} (X = T or F) correspond to the tuning range of the end in the following calculations, $\dot{U}_{|0|}''$ also tuning in 85% of the total length line.

The points 1, 2, 3, 4 are the continuous sampling points in Table 2, the line ? lists fault phase operating voltage variation the of traditional frequency variation distance protection when failure respectively occur at 85 and 80 and 90% of the end of the tuning range, which show that, because of not considering the impact of distributed capacitance, the traditional frequency variation distance protection may occur the beyond malfunction in the positive direction of the external fault when apply to UHV long double lines.

The line? lists the values which are determined by the operating voltage variation formula, which explains the long-line equations deduced by differential equations described by the wave process of transmission lines are correct which apply to frequency variation distance protection.

The validation results show that when it occurs the metal fault at the exit, this protection can take special high-speed action for 3 ms and its resistant transition resistance capability is up to 600 Ω. The validation results also show that it does not exceed malfunction when the positive direction of the external metallic fault and faults with small resistance, this is because we take the distribution parameters algorithm in the calculation and the test results and theoretical analysis are consistant.

CONCLUSIONS

Contrary to UHV AC double Circuit with the same pole,this article give a theoretical analysis and derivation of the calculation expression of a new UHV double circuit single-phase ground distance element measurment impedance and accordingly it puts forward a rapid and resistance to high impedance fault component single-phase ground distance relays. The theory and simulation calculation show that:

Barabanov (2001) frequency variation distance protection deduced by long-line equation and six sequence component when apply in UHV double circuit transmission lines with the same ploe can prevent beyond the malfunction when the fault occurs in the positive direction of the external area.

He *et al*. (2002) The two criterion of distance relay complement with each other to achieve the unity of movement speed and resistant transition resistance ability.

Li *et al*. (2007) The relay is based on distribution parameter and the two sets of criterias contain the origin of coordinates characteristic in the voltage plane characteristic circle, which is advantage to improve the security of the relay, especially it can prevent transient overreach in the early failure.

REFERENCES

Barabanov, Y., 2001. Protection relays of 750kv transmission line in Russia. (He Jiali, Trans In: Report of Academic Workshop of Beijing Society of Electrical Engineering). Beijing.

He, J.L., Y.L. Li and B. Li, 2002. Relay protection for UHV transmission lines: Part two disposition of relay protection. Automation Electric Power Syst., 26: 1-6.

Li, B., J.L. He and H.P. Yang, 2007. Improvement of distance protection algorithm of UHV long transmission line. Automation Electric Power Syst., 31: 43-46.

Liu, S.M., X.N. Lin and C.M. Yang, 2002. Unified expression of fault-component distance relay. Power Syst. Technol., 26: 23-27.

Liu, Z.Y., 2005. UHV Power Grid. Economic Press of China, Beijing, China, pp: 23-100, (In Chinese).

Sui, F.H., T. Chen and G. Li, 1995. On fault component distance relays. Automation Electric Power Syst., 19: 34-37, (In Chinese).

Suonan, J.L., Y.P. Wu and G.B. Song, 2003. Accurate fault location based on distributed parallel transmission line. Proc. CSEE, 23: 39-43, (In Chinese).

Xu, Z.Y., 2002. New Distance Protection of Transmission Line. China Water Conservancy and Hydroppower Press, Beijing, China, pp: 4-78, (In Chinese).