



IMPLEMENTATION OF REACTORS WITH UNGROUNDED NEUTRALS UNDER EXCESS VOLTAGES IN LONG-DISTANCE POWER TRANSMISSION

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ABSTRACT

In long distance power transmission over 500 kV, overlapping is one of the main problems of limiting extreme voltages. In order to eliminate extreme voltages it has been proposed to use star-shaped reactors with ungrounded neutrals, which are connected at the beginning and at the end of the transmission lines in parallel to shunting reactors and the curves of their graphs are shown. The graphs show the maximum values of the fluctuation curves at the neutral of the reactor, at the beginning and at the end of the line.

KEYWORDS: overhead power lines, over voltage, shunt reactors (SR), ungrounded reactors (UR), compensation, traditional shunt compensation, long distance power transmission lines, automatic circuit reclosing (ACR).

INTRODUCTION:

The methodologies of supply systems such as maintaining the voltage within the power system within required limits, reducing losses, improving the system's stability, and the methods that provide mathematical models for research and confidence are constantly improved. Extreme high voltage protection devices and their methods are also being developed in high voltage lines.

Operational practices have shown that in long distance power transmission lines far from 300-350 km operating unloaded behave like a reactive power source, and the line current flows through the generators break down the normal operating mode of the network. In this case, the transformation of generators to reactive power generators makes the network unstable. It is important to connect reactors with transversal compensatory modes in switching modes and high voltage bus bars of the stations (on the power sending and receiving sides) in terms of solution of protection issues in the long-distance power transmission lines. [1-5].

The processes such as automatic reclosing (ACR) of power switches with direct relay protection, rapid rebuilding of systems interconnection, etc. occur due to automatic high-speed reclosing. Almost all practical breakdowns in power transmission lines are accidents that occur due to the length of the line. In this case, a large portion of the disconnections on the 500 kV voltage lines occur due to single-phase short circuits. (Fig. 1) Successful removal of such cases can be done by single-phase auto reclosing. Removal of frequent single-phase short circuits on combined compensation lines 500 kV, single-phase automatic reclosing (ACR) pause should not be less than 0,5 san, minimizing accident modalities should be considered as an urgent issue. [6-9].

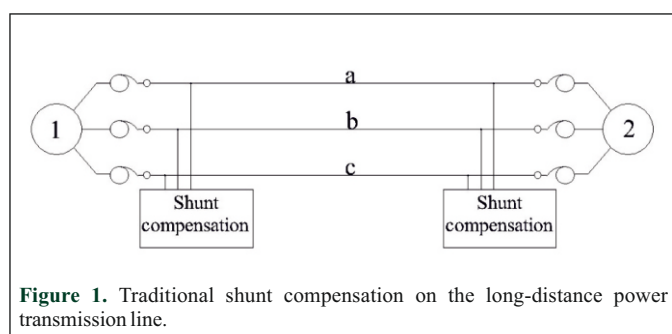


Figure 1. Traditional shunt compensation on the long-distance power transmission line.

The use of compensating reactors that are connected to the neutral of the shunt reactors during the single-phase auto-reclosing pause in conventional shunt compensation schemes leads to the reduction of feeding arc current. Reduction of the feeding arc current to 500 kV for power transmission line, the voltage of which is 50-80 A allows to keep the duration of the single-phase auto reclosing pause without current in the range 50-80 A.

From this point of view, studying single-phase short circuits in the unconventional shunt compensation combined with 500 kV long-distance power transmission lines fed from a single-direction source was considered as one of the important issues. (Fig. 2)

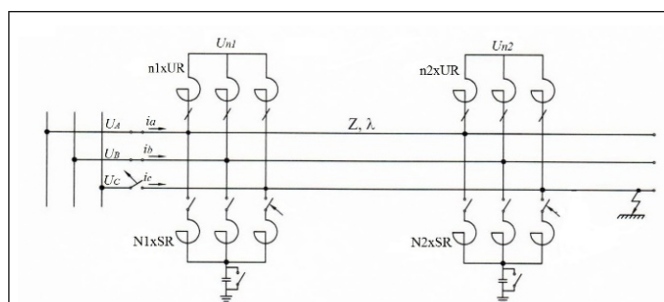


Figure 2. Single-phase short circuits in the unconventional shunt compensation combined with 500 kV long-distance power transmission lines fed from a single-direction source. /moment of disconnection of the damaged phase during short circuit/.

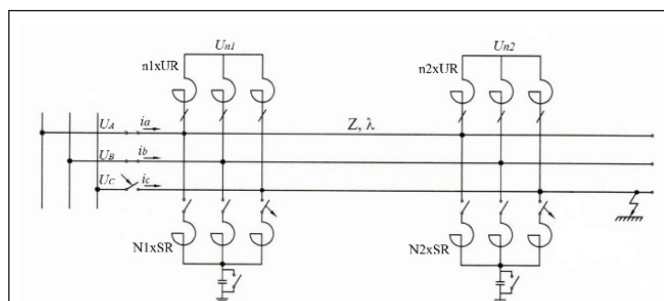


Figure 3. Single-phase short circuits in the unconventional shunt compensation combined with 500 kV long-distance power transmission lines fed from a single-direction source. / duration of pause after short circuit and automatic reclosing moment/.

After emergency disconnections, the damaged phase of the line disconnects on both sides. Then it is automatically reclosed after a certain time called a non-current pause. During the non-current pause period, the residual arc must be disassembled and the separated portion should be deionized. Single-phase short circuits up to 60-70% in higher voltage lines have a non-durable character. That is, they are then eliminated during short-term non-current pauses by restoring the normal layout.

Undertaken researches show that the resistance of the neighboring system on the broken side of the line during the short circuit will have a little impact on the value of voltage at the end of the opened phase. It means that:

$$X_2 = X_2 \circ = 0$$

The single-phase short-circuit pressure value in single-direction connection is expressed as follows:

$$U_{s.sh.c} = K_{s.sh.c} U_{uv} \quad (1)$$

where $U_{s,shc}$ -single phase short circuit, $K_{a,shc}$ -asymmetric coefficient in short circuit mode, and $U_{u,v}$ -voltage at the end of the unloaded line.

In unloaded operation mode, the voltage and asymmetric coefficients are defined as follows:

$$K_{sshc} = \left| e^{j\frac{2\pi}{3}} + \frac{1-m}{2+m} \right|, \quad (2)$$

Where $m = \frac{Z_{d0}}{Z_d}$, $Z_d = \frac{B}{A}$, $Z_{d0} = \frac{B_0}{A_0}$

is relatively straight and zero sequence input resistance, A, B, A_0, B_0 is the polar coefficient 4 corresponding to the straight and zero sequence scheme.

If we take a look at the dependence on the formula (4.2) for a single-phase short-circuit mode, the expression can be summarized as follows:

$$K_{s,shc} = \left| \frac{1-m}{(1+2m)U_{i,m}} + \frac{3m}{1+2m} e^{j\delta} \right| \quad (3)$$

where δ is the displacement angle of the neighboring systems within electromotive force and $U_{i,m}$ -is idling mode.

Formulas (4.2) and (4.3) can be written as matrix:

$$K_{s,shc} = \begin{bmatrix} \frac{1-m}{(1+2m)U_{i,m}} + \frac{3m}{1+2m} e^{j\delta} & -\frac{1}{3}L_1L_2^{-1} & -\frac{1}{3}L_1L_2^{-1} \\ -\frac{1}{3}L_1L_2^{-1} & \frac{1-m}{(1+2m)U_{i,m}} + \frac{3m}{1+2m} e^{j\delta} & -\frac{1}{3}L_1L_2^{-1} \\ -\frac{1}{3}L_1L_2^{-1} & -\frac{1}{3}L_1L_2^{-1} & \frac{1-m}{(1+2m)U_{i,m}} + \frac{3m}{1+2m} e^{j\delta} \end{bmatrix} \quad (4)$$

$$i_1 \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix}, i_{sr1} \begin{bmatrix} i_{srA} \\ i_{srB} \\ i_{srC} \end{bmatrix}, i_e \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix}, i_{ur1} \begin{bmatrix} i_{ntr1A} \\ i_{ntr1B} \\ i_{ntr1C} \end{bmatrix}, u_e \begin{bmatrix} u_A \\ u_B \\ u_C \end{bmatrix}, U_n \begin{bmatrix} N_{n1} \\ N_{n2} \\ N_{n3} \end{bmatrix}$$

Here u_a, u_b, u_c is the phase voltages of reactors with grounded neutrals.

There may be cases of increase of voltage in neutral of the reactors with grounded neutrals in different emergency modes, i.e.:

$$U_n = \frac{U_a + U_b + U_c}{3} \quad (5)$$

U_0 -value in the normal operating mode of the line is equal to zero.

If we look at the calculation scheme, the system formula for the node point at the moment of connection of the three-phase line in the unloaded operation mode of the source will be as follows [2]:

$$\frac{di_T}{dt} = L_{\delta}^{-1}(u_{V,S} - u_{V,N,P} - r i_T), \quad (6)$$

where $u_{V,S}$ -is the voltage of the source

$u_{V,N,P}$ -is the voltage at the node point of the line, and L, r -is the inductive and active resistance of the source.

If we put the variables of the formula (4.6) into square matrices from the third degree:

$$u_{V,S} = \begin{bmatrix} u_{V,S} \sin(\omega t + \varphi) \\ u_{V,S} \sin\left(\omega t + \frac{2\pi}{3} + \varphi\right) \\ u_{V,S} \sin\left(\omega t - \frac{2\pi}{3} + \varphi\right) \end{bmatrix},$$

$$\varphi \left(\frac{\partial u}{\partial t}, u \right) = \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix},$$

$$u_{V,N,P} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix},$$

$$L_{\delta} = \begin{bmatrix} L_{11} & L_{12} & L_{13} \\ L_{21} & L_{22} & L_{23} \\ L_{31} & L_{32} & L_{33} \end{bmatrix},$$

$$r = \begin{bmatrix} L_{11} & 0 & 0 \\ 0 & L_{22} & 0 \\ 0 & 0 & L_{33} \end{bmatrix}$$

When opening a phase in a non-full phase mode, the inter-contact voltage is equal to or greater than the other two phases:

$$U_{ic} = U \cdot \sin(\omega t + \varphi) + 1 \quad (7)$$

is U_{ic} inter-contact voltage here.

When opening both phases in a non-full phase mode, the spaced inter-contact voltage of the switch is increased up to $3,5U_s$, ie:

$$U_{ic} = \sqrt{3} U \cdot \sin(\omega t + \varphi) + \sqrt{3} = 2\sqrt{3} \quad (8)$$

The calculation of the formula (4.6) to define the voltage at the node point of the line $-u_{V,N,P}$ can be written as follows:

$$u_{V,N,P} = (1+G)^{-1} [(Z+Z_s)i_d + u_q - Zi_q - G(\pm u_3) - \theta_1 + \theta_2],$$

where

$$\frac{di_T}{dt} L_{\delta}^{-1} \left[u_M - \left(\frac{Z+Z_s}{1+G} + r \right) i_T - \frac{u_q - Zi_q - G(\pm u_3) - \theta_1 + \theta_2}{1+G} \right] \quad (9)$$

where

$$\frac{di}{dt} = L_T^{-1} [e(t) - u_1],$$

$$\frac{di_{r1}}{dt} = L_{r1}^{-1} u_1,$$

$$\frac{di_{r2}}{dt} = L_{r2}^{-1} u_1,$$

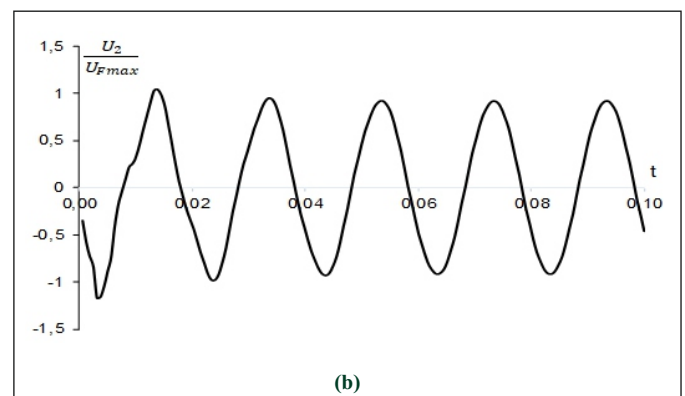
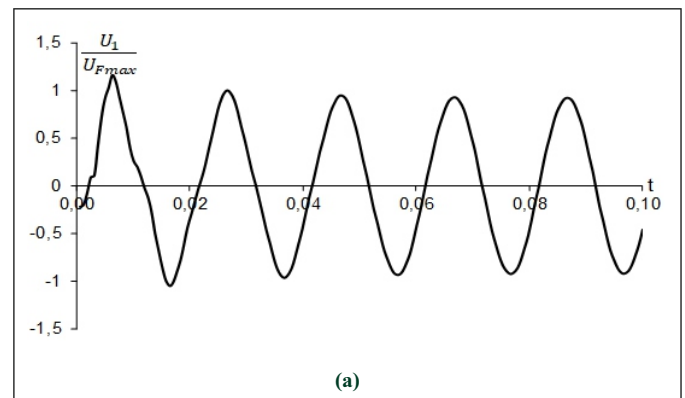
$$\frac{di_{w1}}{dt} = L_{w1}^{-1} (u_1 - u_{01}),$$

$$\frac{di_{w2}}{dt} = L_{w2}^{-1} (u_1 - u_{02}),$$

(10)

$$u = \begin{bmatrix} u_{a1} \\ u_{b1} \\ u_{c1} \end{bmatrix}, i = \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix}, i_p = \begin{bmatrix} i_{pa1} \\ i_{pb1} \\ i_{pc1} \end{bmatrix}, i_q = \begin{bmatrix} i_{qa1} \\ i_{qb1} \\ i_{qc1} \end{bmatrix},$$

SIMULATION RESULTS:



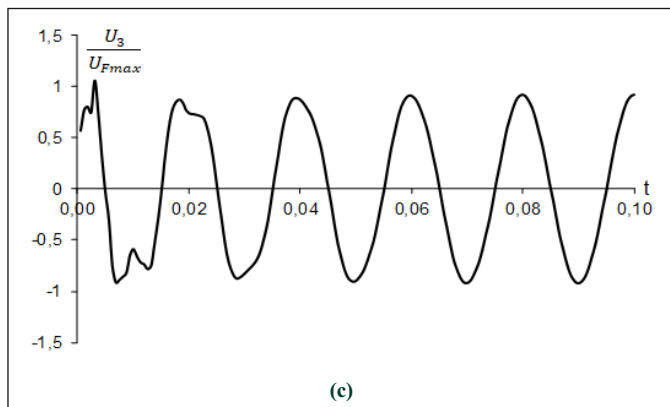


Figure 4. (a), (b), (c) - the change curves of the voltage at the beginning of the line of shunt compensated reactors combined in lines full-phase mode.

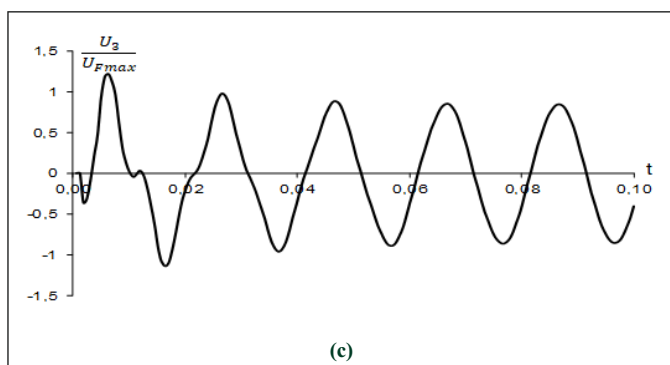
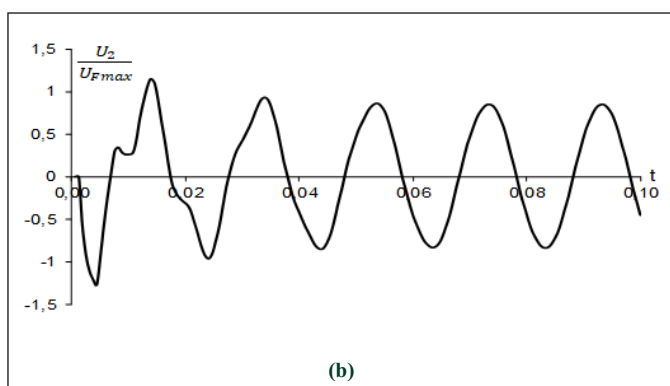
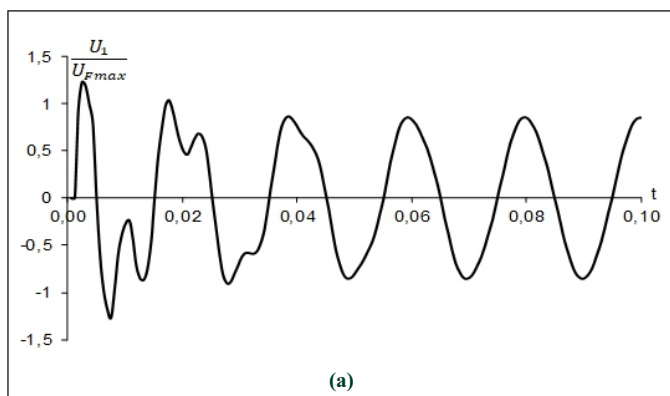


Figure 5. (a), (b), (c) - the change curves of the voltage at the end of the line of shunt compensated reactors combined in lines full-phase mode.

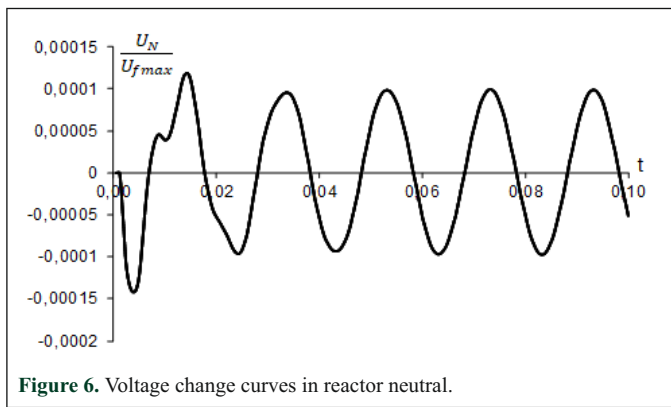


Figure 6. Voltage change curves in reactor neutral.

Table 1. Voltage change curves

Beginning of line			End of Line			Reactor neutral
U_1	U_2	U_3	U_1	U_2	U_3	U_N/U_n
1,17	1,14	1,22	1,16	1,13	1,21	0

CONCLUSION:

If there is no shunt compensation for overhead lines with voltage of 500 kV and 750 kV and length more than 300 km, the feeding arc current exceeds the critical limit of 80 A, in which case the possibility that the current arc has successfully switched off during the opening of the damaged phase is excluded

Application of combined compensation simplifies implementation of single face automatic circuit reclosing (ACR) in higher voltage transmission lines.

In normal regimes $U_n=0$, i.e. there is no tension in the neutral of the ungrounded reactor. The effect of voltage on the isolation of neutral is mostly apparent in connection of lines under single-phase conditions, during incidence of non-symmetric short-circuiting on line and their elimination.

The application of combined compensation simplifies the implementation of single face automatic circuit reclosing (ACR) especially on higher voltage lines. First, there is no need for connection of compensating reactors in the neutral of the shunt reactor in the traditional compensation, and second, only connection of one phase of the shunt reactors, which is identical to the phase of the short circuit, is sufficient to reduce the feeding arc current.

The experiments show that the application of reactors with ungrounded neutrals in long distance power transmission lines makes the stability of the system under emergency modes more dynamic i.e. the system gains more flexible operation principle by providing required and keeping stable voltage over the line.

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