PROBLEM OF DEFINING REAL VALUES FOR CAPACITATE CURRENTS IN ISOLATED SYSTEMS AS WELL PROPER ADJUSTMENTS AND DIRECTING OF EARTH PROTECTION IN DISTRIBUTION GRIDS

Summary: It is very distinguished opinion about capacity currents limited values, not only regarding its value, but at all. Discussion about this subject is very interesting and universal.

Considered are measuring methods for defining of capacity current values, via measured components of ground capacity, cable or air wire.

Direction of earthing protections is achieved is done on very simply and elegant way, by assigning of voltage component on the ends of open triangle and current, pulling of conductors through encircled voltage transformers at the outlets of the same orientation.

Key words: earthing, ground capacity relays direction.

Feature and grid specific with insulated neutral point is possibility of earthing current self-extinguishing without breaking of drive. It is very important, particular for overground wires, at which are large proportion of temporary earhing.

After extinguishing of the arc during temporary failure, insulation is established on the designed value, in order to prevent potential point of multivolume failure.

When in question are cables, temporary failures are very rare, so that self-extinguishing helps for maintenance of uninterrupted power supply, but allows undiscovered point with weakening insulation.

There are provided conditions for appearing of latent failure on the electric grid, of course.

In Table No. 1, are given limited values of current for self-extinguishing within the grids with different voltage values. Data are mainly experimentally defined and on the experience during a practice for more than one year.

During currents lower than limited values, as a rule will occur self-extinguishing of the arc.

Nominal voltage (kV)	Current of demolish failure point (A)
10	35
20	35
30	40
50	60

Table No. 1.

On 6kV cable insulated grids, limited self-extinguishing current amounts to 30A, on 20kV, 35A, and on 35kV grids its value is 45A.

Experience has shown that during specific conditions and for adequate current values it is occurred transition of earthing to multivolume failure.

In Table No. 2, are given values of limited currents:

Nominal voltage of grid (kV)	6	10	15-20	35
Limited values of current (A)	30	20	15	10

Table No. 2.

It can be noticed discrepancy of self-extinguishing current values and limited currents values during which is occurred transfer of earthing to multivolume short circuit.

There is great difference on equipment features for defined electric grids.

In Germany, for instance, very rare is occurred multivolume short circuit from the earthing, while in many other countries (east European) it is not a case.

According to analyse of conditions on grid and equipment features, it can be claimed that data provided in Table No. 2, strictly reflect limited current values for transition to intermediate phase failures for cable grids 6-10kV with lead-oily cables.

For overground cables, expressed values are too low, and data from Table No. 1 better reflects adequate circumstances on the grid.

However, current values (Table No. 2) are competent for defining of transition possibilities from the ordinary earthing to multivolume failure.

During minimal earthing currents up to for example 10A, it can occur multivolume switching off and on of arc, what as result has very high excess voltage, as well on functional and on phases under earthing.

In Table No. 3, are given limited values of intermittent excess voltages, and as per Petersen and Peters Slipijen theories.

Excess voltage factor		Demaged phase	Functional phase
Petersen	with attenuation	3.51	2.87
	without attenuation	7.5	6.00
Petersen-Slipijan	with attenuation	2.62	1.80
	without attenuation	3.50	2.00

Table No. 3.

Excess voltage factor is as follow:

$$K = \frac{Um}{\frac{\sqrt{2}}{\sqrt{3}} Un}$$

Where: Um – is maximal excess voltage value.

There are different factors, which limit excess voltage value, that is affects attenuation.

Excess voltage values given in Table No. 3 are calculated for defined possible conditions in electric grids.

It can be considered that theory by Petersen shows exact occurrence of failures on cables, and theory by Peters Slipijen occurrences on the overvoltage wires and in plants where is arc established in the air.

Intermittent excess voltages can occur on electric grids where by the earth fault compensation unit is compensated influence of capacity currents. Here is the voltage on the phase established slowly after of arc extinguishing, so that it is low possibility of additional switching on.

Also, excess voltages are lower values at grids earthed via small impedance, or directly earthed, because large earthing currents cannot be extinguished by themselves.

Intermittent excess voltages can be controlled by use of excess voltages conductors, and if it is not carried our right selection it occurs multivolume failures, if there on the grid are points with weaken insulation.

Problem at cable grids is that weaken insulation points remain, on one hand drive does not endure and on other there is provided possibility for creating of latent, multivolume failures.

There is opinion that it is better not to limit **Iz** to value of self-extinguishing arc, but to allow for arc to demolish failure point.

Aim is in elimination of each possibility for weaken insulated points on the electric grid.

In Russian it is practice in connecting of the cable to elevated voltage value during defined time interval, as well as its overhaul in order to provide perfect insulation level.

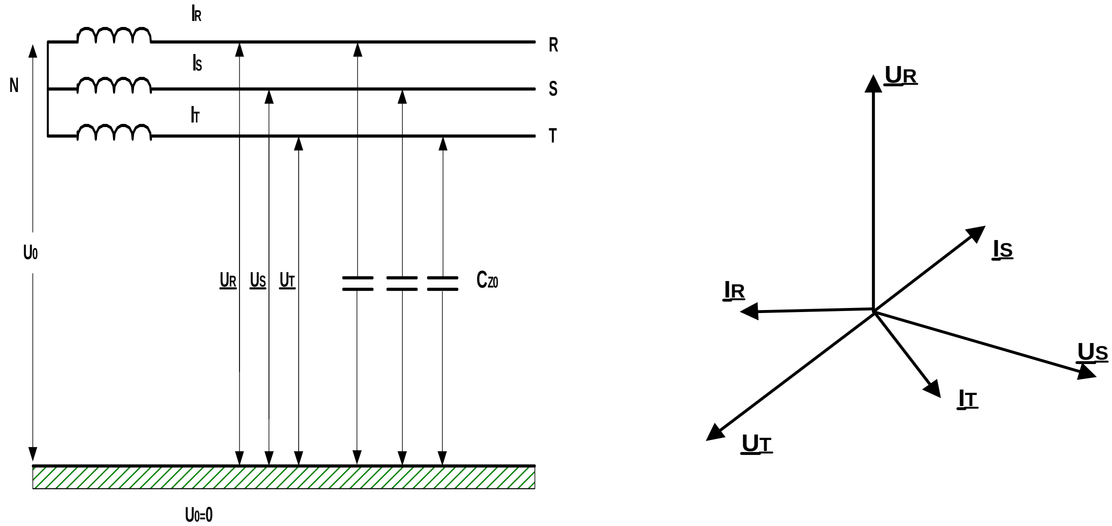

Figure No. 1. Circumstances on sound grid with insulated star point

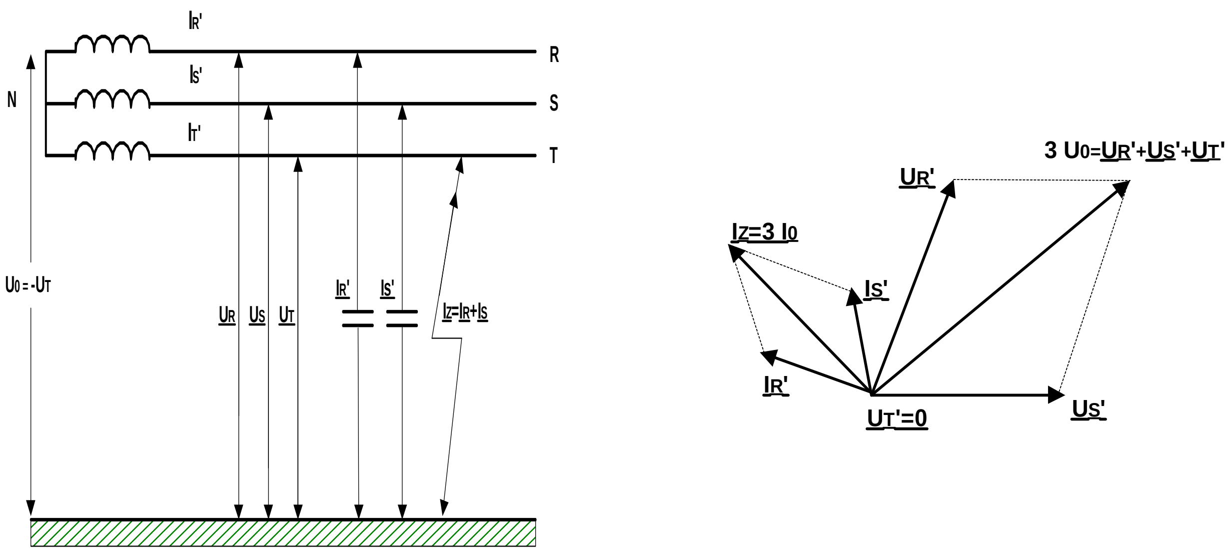

Figure No. 2. Circumstances on the grid during earthing in **T** phase

During metal earthing of one phase (**T**), voltage falls to zero, that is to earth potential

Star point voltage becomes equal to the amount, and opposite per sign, of phase voltage in failure **Uo= -Ut**.

Because phase T is on the ground potential, and line voltages remain further equal, voltages of undamaged phases are increasing to the amount of line voltages in regard to ground:

$$U_R'=U_R+U_0=U_R-U_T=U_{RT}$$
$$U_S'=U_S+U_0=U_S-U_T=U_{ST}$$

$$U_T'=U_T+U_0=U_T-U_T=U_0$$

Voltages $\mathbf{U_R'}$ and $\mathbf{U_S'}$, contribute to appearance of currents values $\mathbf{I_R'}$ and $\mathbf{I_S'}$ which surpass for 90º (π/2).

These currents are summarized by vectors through earthing point, so that erathing current amounts:

$$I_Z=I_R'+I_S'=\sqrt{3}\,I_R'=\sqrt{3}\,U_R'\omega C_{Z0}=3\omega C_{Z0}U_f=3I_0$$

From above mentioned can be seen that during earthing are appeared voltage and zero component current:

$$U_0=\frac{1}{3}(U_{R'}+U_{S'}+U_{T'})=-U_T$$

Ground capacity $\mathbf{C_{ZO}}$ of overground wires depends on distance of wires from the ground, conducers' disposition on the pole head and number of ground cables.

Approximate values: **(3-5)·10^{-9} F/km=(3-5)n F/km** for air wires and **(200-400)· 10^{-9} F/km=(200-400) n F/km** for cable grid.

Earthing currents are in cooperation with short circuit and overload currents, relatively small, except at very extended cable grids.

It is between limits of a few amperes and higher. This current influences demolishing on the point of failure, because it usually flows through arc.

Operation of the grid under earthing is not recommended, disregarding the regulation which allows it during 2 hours, because during a failure through arc it appears excess voltage in the entire consume, which can initiate breach and jump even on the sound phases.

It is necessary to find a wire under the erthing and to eliminate arising failure.

Direction of earthing protection has to be correctly defined and checked in practice, in order to prevent wrong reaction of used relays.

Greater numbers of earthings is with temporary features and appear during switching off voltage.

Capacity currents are possible to be measured during earthing simulation, via current reducer, although there is open question of higher harmonic transferring from primary to secondary.

Also, earthing current can be measured directly by use of ampere claws, although question of harmonic components registration remains open.

Data about earthing current can be provided on indirect way by measuring of ground cable features or overground wires. Capacity should to be measured due to checking of rather different data given in catalogues, where sometimes is not make difference between ground and drive capacity.

Method is given by which it is possible to establish values of capacity according to ground for each phase separately, because of selection the most favorable case, due to nonsymmetrical existence in cable construction or overground wire.

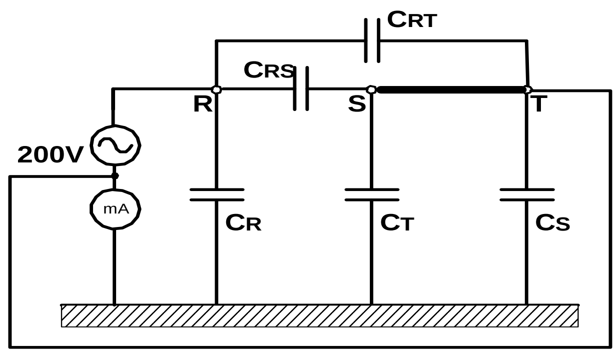

Figure No. 3. Measuring of ground capacities

$$X_{CR}=\frac{U}{I}\quad;\quad \frac{1}{\omega CR}=\frac{U}{I}\quad;\quad \omega C_R=\frac{U}{I}\quad;\quad C_R=\frac{I}{\omega U}$$

$$C_R=\frac{I}{2\pi f U}=\frac{I}{100\pi U}=\frac{I}{314U}\qquad \text{za } f = 50\text{Hz}$$

On the same way we control values of ground capacities $\mathbf{C_S}$ and $\mathbf{C_T}$.

At the figure we can see that $\mathbf{C_S}$ and $\mathbf{C_T}$ do not have any influence considering bridged mill. ammeter which inner resistance is extremely low.

Circuit which flows through intermediate phase capacity $\mathbf{C_{RS}}$ and $\mathbf{C_{RT}}$ is lead to the generator U=220V, but passing by mill. ammeter so that it is not measured.

Ground capacities can be measured to the following way, with neglected non symmetry and some different results.

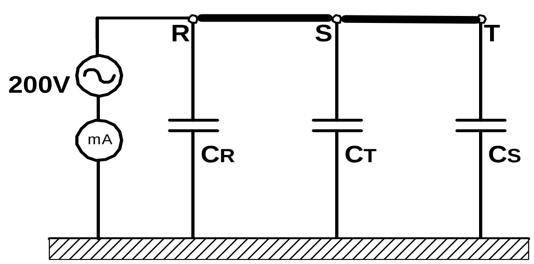

Figure No.4. Ground capacities measuring

$$X_{Ce}=\frac{U}{I}\quad;\quad \frac{1}{\omega Ce}=\frac{U}{I}\quad;\quad \omega Ce=\frac{I}{U}\quad;\quad Ce=\frac{I}{\omega U}\quad;\quad Ce=\frac{I}{2\pi f U}=\frac{I}{314U}$$

$$Ce = 3C_R \Rightarrow C_R=\frac{Ce}{3}$$

$$C_R = \frac{I}{3 \cdot 314U} = \frac{I}{942U}$$

Basically during control of directed earth fault current protection, it is recommended that level of relay going into operation has to be adjusted to minimal value. This is very important in order to ensure necessary sensitivity and during switching of several outlets, by which the value of capacity current is losing.

For reactions of the earth fault current protection on the outlet 1, important are cable lengths and air wires on all other outlets, while length of the very outlet 1 is not important.

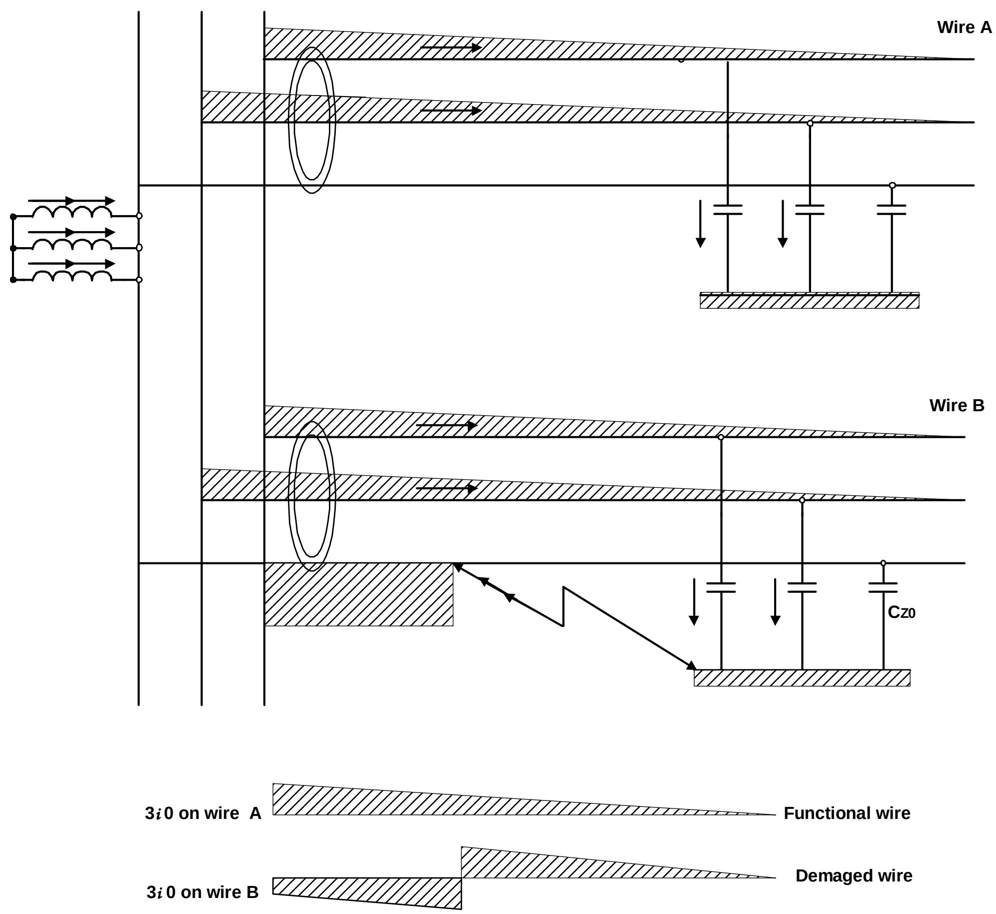

Figure No. 5. Currents flow during earth fault current on the insulated grid

The failure point is supplied by the capacity current of the entire grid. Directed relays are connected to the voltage and current of zero component and acts at power direction from the wire to busbars.

The earth fault current point represents source of current of zero component, from where it is spread on all wires. Only directed relay will act on the wire which is damaged. Directed relay are to be maximally sensitive to capacity current and sensitivity are to be sufficiently high in order to have its reaction during minimal values, too.

At the Figure No. 5 is shown flow of the zero current components on the sound and damaged wire.

It is a great problem to check direction of the earth fault current protection on the each outlet separately, because it will mean analyse of the complete wiring and possible provoking of artificial earth fault current protection what is connected to the arising of excess voltage waves by which is imperil insulation of the system.

The most suitable way for direction checking is to be performed of assigning voltage-current information from the one point. At the ends of the open triangle, it is given voltage in value of 100V~, which appears during real earth fault current.

Of course, the ends of the voltage transformer are disconnected, and voltage information is forwarded to all relays. Through encircled voltage transformers in each cell is pulled conductor with the same direction (e.g. from above to below) and through it is passing current information.

We achieve phase shift between voltage and current of 90º, that is 270º, as much ac amounts shifting between $\mathbf{U_0}$ and $\mathbf{I_0}$, during real earth fault current.

If all relays are directed at the same way, by increasing of current value, and during U=100V, it comes to reaction of directed earth fault current protection on all outlets. If it is not such, we perform direction toward outlet to which we know that is correctly oriented.

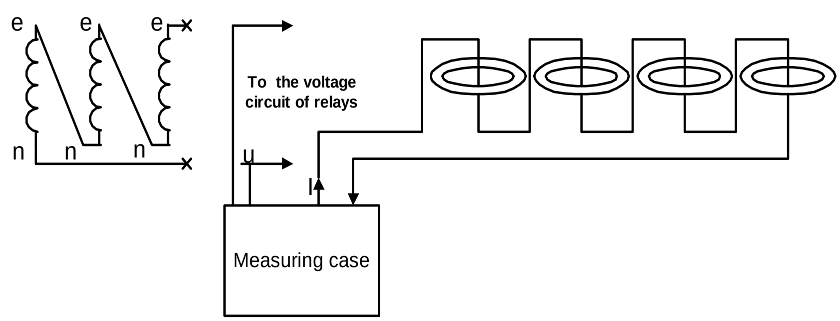

Figure No. 6. Control and adjustment of earth fault current protection direction on the outlets at insulated grid

With good organization of operation, 10-15 outlets per system of busbar can be examined for 30-40 minutes, what confirms a fact that in question is elegant measuring way.

Primary is always performed examination, even when instead of encircled voltage transformers, in question are usual current reducers.

Literature: Earth fault current on grids 35 and 6kV by M.Fjodorov

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