ACHIEVEMENT OF AN ABSOLUTELY SELECTIVE DISTANCE PROTECTION SYSTEM AT AN AUTO SUPPLY. CASE STUDY AT 200 MVA

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Operational experience of such electrical equipment demonstrated that in the operational command an autotransformer (AT) 200 MVA cannot operate and it has to be disconnected as the unavailability of the protections for internal defects can only work up to a minimum period unavailability remedy for distance protection, considering the absence of selectivity and increases the elimination of fault time or of the earth fault protection current. This article presents an original perspective on the AT protection with a distance protection, which eliminates the above mentioned conditions.

Keywords: autotransformer, protection system, operating system

2. Introduction

Nowadays, an absolutely selective distance protection can't be achieved for a high power autotransformer, because its operating conditions require modification of the electrical parameters depending on the system, which is why AT distance protection are considered backup protection [1].

This paper presents an original method of a perfectly possible protection in the actual state of development of digital terminals, absolutely selective, just as a (numeric or electromechanical) longitudinal differential protection – basic protection for AT.

2. Purpose of autotransformer operation

2.1. Operating modes

The descending regime, like the ascending regime is the most economical system for transmitting power from high voltage lines in medium and low voltage networks and vice versa, because the power transferred by electromagnetic coupling is less than the nominal winding power. Combined regime is a regime in which the common winding can overload both on electromagnetic coupling power transmission from the medium voltage network to the low voltage network and on transmission of the same power type from the low voltage network to the high and medium voltage networks.

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2.2. Voltage control

An important role in the operation and management of power systems plays the voltage control that is made through AT and can be made by longitudinal, transverse or longitudinally-transverse adjustment.

Load switching of AT plots allows increasing transport capacity of the system by reducing the total impedance.

Thus, if the value of the High Voltage (HV)/Low Voltage (LV) transformation ratio decreases, and increases on the HV / Medium Voltage (MV) level, then the voltage remains constant on the MV side.

This change in electrical parameters by varying the number of turns in a winding, usually in the one of higher voltage, specific in such units of the power system in which the reactive power flow shows large variations and changes of direction, cause changes in AT reactance, as shown in Table 1, which means different contributions in the default mode of direct sequence, inverse and acyclic reactance.

3. AT operation equations in stationary state

For the descending regime of the autotransformer we have the following equations [2]**:**

$$k_a = E_1 / E_2 = w_1 / w_2 = U_1 / U_2 \tag{1}$$

$$\underline{I}_1 + \underline{I}_2 = \underline{I}_{12}\,;(\underline{I}_2 = k_a \underline{I}_1) \tag{2}$$

$$\underline{I}_1 + \underline{I}_2 = \underline{I}_{10} = \underline{I}_{0W} + \underline{I}_{\mu} \tag{3}$$

$$\begin{aligned} \underline{U}_1 &= \underline{Z}_{A\sigma}\underline{I}_1 + \underline{Z}_{c\sigma}\underline{I}_{12} - \underline{E}_1 \\ -\underline{U}_2 &= \underline{Z}_{c\sigma}\underline{I}_{12} - \underline{E}_2 \end{aligned} \tag{4}$$

The significance of these parameters is:

k_a – voltage ratio rated, AT is more economical if this ratio is close to 1; E_1/E_2 – electromotive force (e.m.f.) of primary and secondary side; $\underline{U}_1/\underline{U}_2$ – voltage rated of primary and secondary side; w_1/ w_2 – number of turns of the primary winding of the respective secondary; $\underline{I}_1$, $\underline{I}_2$ – current rating primary, current rating secondary $\underline{I}_{ow}$, $\underline{I}_{\mu}$ – current intensity which causes Joule losses that the magnetic core (Foucault currents); $\underline{I}_{12}$ – current through the common winding of AT; $\underline{Z}_{A\sigma}$ – circuit impedance of the primary winding; $\underline{Z}_{C\sigma}$ – a portion of the common winding impedance.

Replacing (2) and (3) in (4) we obtain:

$$\begin{aligned} \underline{U}_1 &= [\underline{Z}_{A\sigma} + \underline{Z}_{c\sigma}(1-k_a)]\underline{I}_1 + \underline{Z}_{c\sigma}k_a\underline{I}_{10} - \underline{E}_1 \\ -\underline{U}_2^{'} &= \underline{Z}_{c\sigma}k_a(k_a-1)I_2^{'} + \underline{Z}_{c\sigma}k_a\underline{I}_{10} - \underline{E}_2^{'} \end{aligned} \tag{5}$$

In equations (5) the secondary voltage and current are relative to the primary winding.

Electromotive force $\underline{E}_1$, $\underline{E}_2$ are determined by the magnetic flux which is proportional to the magnetizing current Iμ so we can write the equation [3]:

$$\underline{E}_1 = \underline{E}_2 = -j\underline{X}_\mu \underline{I}_\mu = -j\underline{R}_w \underline{I}_{0w} = -\underline{Z}_0 \underline{I}_{10} \tag{6}$$

$$\text{where} \quad \underline{Z}_0 = \frac{j\underline{R}_w \underline{X}_\mu}{\underline{R}_w + j\underline{X}_\mu} \tag{7}$$

these relationships can build the equivalent circuit in Fig. 1 [4].

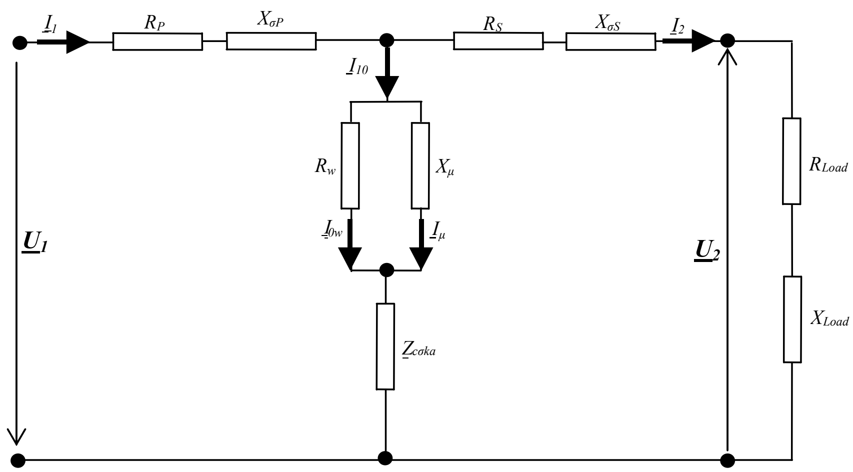


Fig. 1 – Equivalent diagram of an auto electric operation

Significance of measurements in Fig. 1 is:

$\underline{U}_1 / \underline{U}_2$ - voltage rating primary / voltage rating secondary

$\underline{I}_P / \underline{I}_S$ - current rating primary / current rating secondary

R_P / R_S - ohm value resistance first winding / common winding

$\underline{I}_{10} = \underline{I}_{0w} + \underline{I}_\mu$ - current for stray loss

$X_{\sigma P} / X_{\sigma S}$ - ohm value reactance first winding / common winding

R_w / X_μ - reluctance/ magnetizing reactance

$Z_{\sigma ka} =$ - impedance for stray loss

$Z_{Load} = \sqrt{R^2{}_{Load} + X^2_{Load}}$ - load impedance for systems

R_{Load} / X_{Load} - resistance of systems / reactance of systems

Autotransformer ensure transfer of power as electromagnetic linkage and conduction.

Relationship between power transmitted electromagnetic *($\underline{u}_2\underline{i}_2$)* and the total power *($\underline{U}_2\underline{I}_2$)* is given by [4]:

$$\frac{\underline{u}_2\underline{i}_2}{\underline{U}_2\underline{I}_2} = 1 - \frac{\underline{U}_1}{\underline{U}_2} = \frac{w_1}{w_2 + w_1} \tag{8}$$

Fig. 2 is suggestive looks conventional voltage and current circulations. AT can be ascending regime when energized low voltage *(w_2)*, and descending regimen when energized high voltage side *($w_1 + w_2$)* [5]

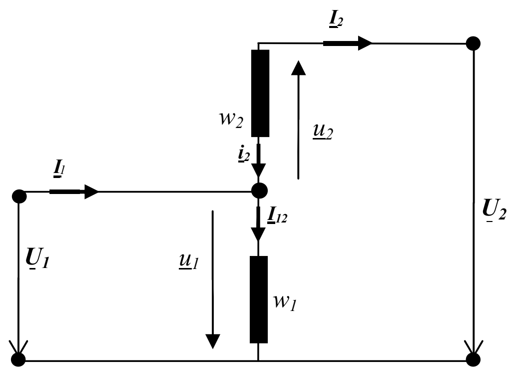


Fig. 2 – Another equivalent diagram of an auto electric operation

Short circuit impedance determined by short circuit transformer test report

The autotransformer studied in our case allows voltage regulation under load in the range of ± 12 x 1.25% of the nominal voltage of 231 kV, with ± 13 adjustment steps (plots).

Short circuit voltages are measured on nominal plot, they are relative to the nominal power of FIT winding, respectively at 200 MVA for all three coiling.

The short circuit relative nominal voltage is [5]:

$$u_{ka} = Z_{ka} I_{1n} / U_{1n} = \frac{I_{1n}}{U_{1n}} \left| Z_{A\sigma} + Z_{C\sigma}(k_a - 1)^2 \right| \tag{9}$$

Based on these measured values were calculated for all positions reactance transformer tap changer (1 ÷ 27) and have obtained the values shown in Table 1

Winding reactance are determined by calculation and are related to the nominal voltage of the primary winding, these values are the ones needed in the design of the protection system and coordination of protection settings.

Impedance voltage test for short circuit winding HV/LV, obtain u_{12}, u_{13}, u_{23} impedance triangle and Z_1 is impedance imitation for HV, Z_2 is impedance imitation for LV and Z_3 is impedance imitation for TV, U_n is voltage rated of AT and S_{ij} *($i=\{1,2,3\}; j=\{1,2,3\}$)* is apparent power of AT [3].

Table 1

Technical characteristics determined by measurements (short-circuit voltage) and calculated (short circuit reactance) of a three-phase power AT

Tap Position (Changer)	***Un1 [kV] rated high voltage 220 kV (HV)***	***Un2 [kV] rated voltage 110 kV (LV)***	***Un3 [kV] rated voltage 10,5 kV (TV)***	***Impedance Voltage Winding HV/LV (200 MVA) -Measuring (%)***	***Impedance Voltage Winding HV/TV (200 MVA) Measuring (%)***	***Impedance Voltage Winding HV/LV (200 MVA) Measuring (%)***	***Reactance Winding HV/LV (200 MVA) - Calculated (Ω)***	***Reactance Winding HV/TV (200 MVA) - Calculated (Ω)***	***Reactance Winding LV/TV (200 MVA) - Calculated (Ω)***	***Reactance Winding HV (200 MVA) -Calculated (Ω)***	***Reactance Winding LV (200 MVA) -Calculated (Ω)***	***Reactance Winding TV (200 MVA) -Calculated (Ω)***
1	265.65	121	10.5	9.55	9.62	5.4	33.7	113.15	63.51	**41.67**	-7.97	71.48
2	262.76	121	10.5	9.55	9.62	5.4	32.9	110.7	62.14	40.76	-7.8	69.94
3	259.87	121	10.5	9.55	9.62	5.4	32.25	108.28	60.78	39.87	-7.63	68.41
5	254.1	121	10.5	9.55	9.62	5.4	30.83	103.52	58.11	38.12	-7.29	65.4
6	251.21	121	10.5	9.55	9.62	5.4	30.13	101.18	56.8	37.26	-7.13	63.92
7	248.32	121	10.5	9.55	9.62	5.4	29.45	98.87	55.5	36.41	-6.96	62.46
8	245.43	121	10.5	9.55	9.62	5.4	28.76	96.58	54.22	35.57	-6.8	61.02
9	242.55	121	10.5	9.55	9.62	5.4	28.09	94.32	52.95	**34.73**	-6.64	59.59
10	239.66	121	10.5	9.55	9.62	5.4	27.43	92.09	51.69	33.1	-6.49	58.18
12	233.88	121	10.5	9.55	9.62	5.4	26.12	87.71	49.23	32.3	-6.18	55.41
13	*231*	*121*	*10.5*	*9.55*	*9.62*	*5.4*	*25.48*	*85.56*	*48.02*	*31.51*	*-6.03*	*54.05*
15	*231*	*121*	*10.5*	*9.55*	*9.62*	*5.4*	*25.48*	*85.56*	*48.02*	*31.51*	*-6.03*	*54.05*
17	225.22	121	10.5	9.55	9.62	5.4	24.22	81.33	45.65	29.95	-5.73	51.38
18	222.33	121	10.5	9.55	9.62	5.4	23.6	79.26	44.49	**29.19**	-5.58	50.07
19	219.45	121	10.5	9.55	9.62	5.4	23.0	77.21	43.34	28.43	-5.44	48.78
20	216.56	121	10.5	9.55	9.62	5.4	22.39	75.2	42.21	27.69	-5.3	47.51
21	213.67	121	10.5	9.55	9.62	5.4	21.8	73.2	41.09	26.96	-5.16	46.25
22	210.78	121	10.5	9.55	9.62	5.4	21.22	71.24	39.99	26.23	-5.02	45.01
23	207.9	121	10.5	9.55	9.62	5.4	20.64	69.3	38.9	25.52	-4.88	43.78
25	202.12	121	10.5	9.55	9.62	5.4	19.51	65.5	36.77	24.12	-4.61	41.38
26	199.23	121	10.5	9.55	9.62	5.4	18.95	63.65	35.73	23.44	-4.48	40.21
27	196.35	121	10.5	9.55	9.62	5.4	18.41	61.81	34.7	**22.76**	-4.35	39.05

$$Z_1 = \left(\frac{u_{12}}{S_{12}} + \frac{u_{13}}{S_{31}} - \frac{u_{23}}{S_{23}} \right) \frac{U_n^2}{2 \times 100} [\Omega / phase] \quad (10)$$

$$Z_2 = \left(\frac{u_{23}}{S_{23}} + \frac{u_{12}}{S_{12}} - \frac{u_{13}}{S_{31}} \right) \frac{U_n^2}{2 \times 100} [\Omega / phase] \quad (11)$$

$$Z_3 = \left(\frac{u_{13}}{S_{31}} + \frac{u_{23}}{S_{23}} - \frac{u_{12}}{S_{12}} \right) \frac{U_n^2}{2 \times 100} [\Omega / phase] \quad (12)$$

4. Theory of distance protection operation for an AT

Specific features of these electric equipments that have two power supplies require protection solutions for both internal and external faults – distance protection.

Internal defects are eliminated in quick step or stage 2 time-delayed, and the external ones by corresponding time delay of electrical distance to the protection site.

Its operation is based on the measurement of electrical quantities, currents and voltages on the same side of the AT and determination of impedance (practically of the reactance to the fault site).

Fig. 3 shows the diagrams of distance protection operation fitted to the 220 kV or 110 kV AT protection areas, so that for 60% of the AT reactance, defects are eliminated quickly from one end, the defects that occur above this percentage, their elimination will be time delayed in the second stage.

Likewise, for refusal of protection or breaker on the lines adjacent to the stations A 220 kV and A 110 kV the reservation of short-circuit elimination is via higher stages.

The stepwise driving feature of distance protection shows how to obtain selectivity by coordinating operation time with measured impedances. It can be seen in the chosen example that a defect in point k1 will be rapidly eliminated (t1) by the distance protections side 220 kV - PD_1 and side 110 kV - PD_2 time-delayed.

Observing the selectivity principle requires on establishment of settings (impedance and time) to take into account all possible errors: relay accuracy for impedance measurement, precision of the time element, system conditions that can increase or decrease the impedance "seen" by the relay.

For this reason, current practice in the time field is of 0,4 – 0,5 s selectivity step. In determining the adjustments one must take into account: impedance-source ratio and line ratio, directional element sensitivity, sensitivity of measuring element (or elements), current and voltage measurement transformer type and system asymmetry.

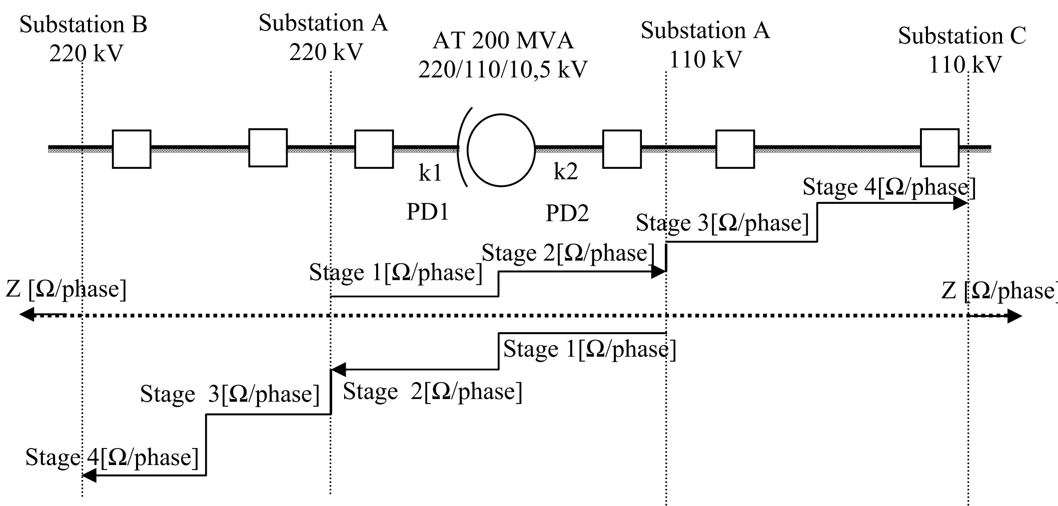


Fig. 3 – Diagrams of distance protection operation fitted to the 220 kV or 110 kV AT 200 MVA

Setting the quick stage is done by the following relationship [15]:

$$Z_1 = 0{,}8(Z_{AT\min}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} \tag{13}$$

where $u_{ka\ min}$ is minimum impedance voltage corresponding tap AT, and S_n is apparent power of AT, in this relationship equal 200 MVA.

Each change of direct reactance is followed by a new adjustment:

$$Z_{1tap2} = 0{,}8(Z_{ATtap11}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 26{,}96\Omega/\,phase \tag{14}$$

$$Z_{1tap3} = 0{,}8(Z_{ATtap10}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 26{,}32\Omega/\,phase \tag{15}$$

$$Z_{1tap12} = 0{,}8(Z_{ATtap1}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 20{,}89\Omega/\,phase \tag{16}$$

$$Z_{1tap13} = 0{,}8(Z_{ATtap0}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 20{,}38\Omega/\,phase \tag{17}$$

$$Z_{1tap16} = 0{,}8(Z_{ATtap-1}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 19{,}88\Omega/\,phase \tag{18}$$

$$Z_{1tap23} = 0{,}8(Z_{ATtap-8}) = 0{,}8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 16{,}51\Omega/\,phase \tag{19}$$

$$Z_{1tap26} = 0,8(Z_{ATtap-11}) = 0,8\frac{u_{ka\min}}{100}\frac{U_n^2}{S_n} = 15,16\Omega / \, phase \quad (20)$$

By not being able to set but only one impedance value, the minimum values were chosen against which to compare the protection desensitization, so as not to trigger the unselective AT (by instantaneous values) on fault on the adjacent bar, therefore to a defect exterior to the differential area.

We are considering the following algorithm for Z2 [15]:

$$Z_2 = 0,8\left(Z_{AT\min} + k_{sch}\min Z_{L1\min}\right) \quad (21)$$

Based on the following assumptions:

$$Z_{L1\min} = 10\Omega/phase \quad (22)$$

and $k_{schemes} = 1$ (schems factor denotes as k_{sch}) (23)

$$Z_{2tap2} = 0,8\left(Z_{ATtap11} + k_{sch}Z_{L1\min}\right) = 34,96\Omega/phase \quad (24)$$

$$Z_{2tap6} = 0,8\left(Z_{ATtap7} + k_{sch}Z_{L1\min}\right) = 32.1\Omega/phase \quad (25)$$

$$Z_{2tap9} = 0,8\left(Z_{ATtap4} + k_{sch}Z_{L1\min}\right) = 30,47\Omega/phase \quad (26)$$

$$Z_{2tap12} = 0,8\left(Z_{ATtap1} + k_{sch}Z_{L1\min}\right) = 28,89\Omega/phase \quad (27)$$

$$Z_{2tap18} = 0,8\left(Z_{ATtap0} + k_{sch}Z_{L1\min}\right) = 26,88\Omega/phase \quad (28)$$

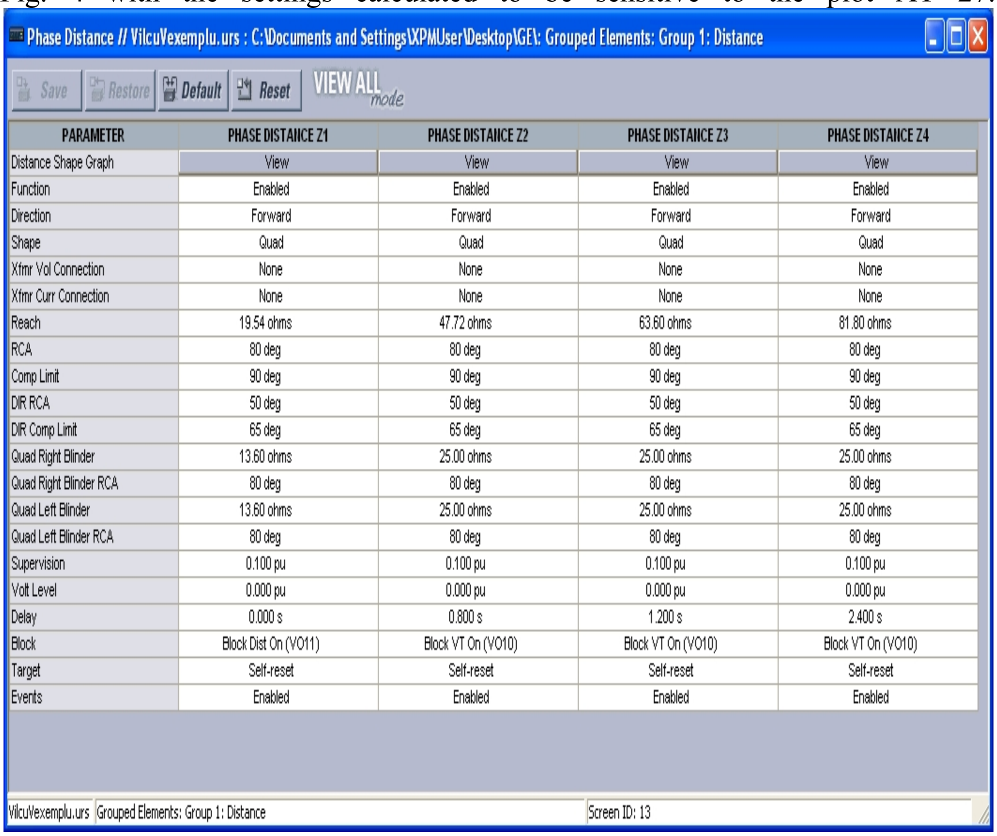
$$Z_{2tap24} = 0,8\left(Z_{ATtap-9} + k_{sch}Z_{L1\min}\right) = 24,56\Omega/phase \quad (29)$$

$$Z_{2tap26} = 0,8\left(Z_{ATtap-11} + k_{sch}Z_{L1\min}\right) = 23,16\Omega/phase \quad (30)$$

In the philosophy of protection k_{sch} are overeating or scheme of coefficient and the ratio of total current and fault current own source (AT). The worldwide development in the last 20 years of new solutions and equipment in the field of secondary circuits and numerical relays allows my own solution that I propose for the first time to parameterize differently all sets of available adjustments in the relay in order to obtain the desired selectivity:

I took for illustration purposes a D60 relay manufactured by General Electric, an older version 3.1, exactly because it has different groups of adjustments in different sets, thus allowing versatility and covering 61.5% of the proposed selectivity requirement. Surely a numeric terminal that can have 26 sets of adjustments could ensure us absolute selectivity, which we need to eliminate defects and abnormal regimes occurred in the primary equipment of AT transport or processing or adjacent bars.

In first set of adjustments desensitized to the minimum AT reactance, shown in Fig. 4 with the settings calculated to be sensitive to the plot AT 27.



Phase Distance // VilcuVexemplu.urs : C:\Documents and Settings\XPMUser\Desktop\GE\: Grouped Elements: Group 1: Distance

Save Restore Default Reset VIEW ALL mode

PARAMETER	PHASE DISTANCE Z1	PHASE DISTANCE Z2	PHASE DISTANCE Z3	PHASE DISTANCE Z4
Distance Shape Graph	View	View	View	View
Function	Enabled	Enabled	Enabled	Enabled
Direction	Forward	Forward	Forward	Forward
Shape	Quad	Quad	Quad	Quad
Xfmr Vol Connection	None	None	None	None
Xfmr Curr Connection	None	None	None	None
Reach	19.54 ohms	47.72 ohms	63.60 ohms	81.80 ohms
RCA	80 deg	80 deg	80 deg	80 deg
Comp Limit	90 deg	90 deg	90 deg	90 deg
DIR RCA	50 deg	50 deg	50 deg	50 deg
DIR Comp Limit	65 deg	65 deg	65 deg	65 deg
Quad Right Blinder	13.60 ohms	25.00 ohms	25.00 ohms	25.00 ohms
Quad Right Blinder RCA	80 deg	80 deg	80 deg	80 deg
Quad Left Blinder	13.60 ohms	25.00 ohms	25.00 ohms	25.00 ohms
Quad Left Blinder RCA	80 deg	80 deg	80 deg	80 deg
Supervision	0.100 pu	0.100 pu	0.100 pu	0.100 pu
Volt Level	0.000 pu	0.000 pu	0.000 pu	0.000 pu
Delay	0.000 s	0.800 s	1.200 s	2.400 s
Block	Block Dist On (VO11)	Block VT On (VO10)	Block VT On (VO10)	Block VT On (VO10)
Target	Self-reset	Self-reset	Self-reset	Self-reset
Events	Enabled	Enabled	Enabled	Enabled

VilcuVexemplu.urs Grouped Elements: Group 1: Distance Screen ID: 13

Fig. 4 - Capture the relay distance D60 v. 3.1 settings set 1

Significance of main sizes, read from the bottom up, occurring in this capture is:

- Events - by activating this function are recorded events, faults, oscillogram, fault locator make post - crash analysis.
- Target - auto reset signaling
- Block - an operand in logical scheme which block the relay protection function
- Delay - delay time for each step
- Quad Right Blinder

- Phase distance Z1 (PHS DIST Z1 XFMR VOL) - used when a Current source is on one side of AT and voltage source on the other side, is a correction voltage phase currents

- Supervision - for over 2 steps, the minimum current threshold activation function for it to remain sensitive but not act in burning fuse

Graph according to the adjustments set1 is shown in Fig. 5:

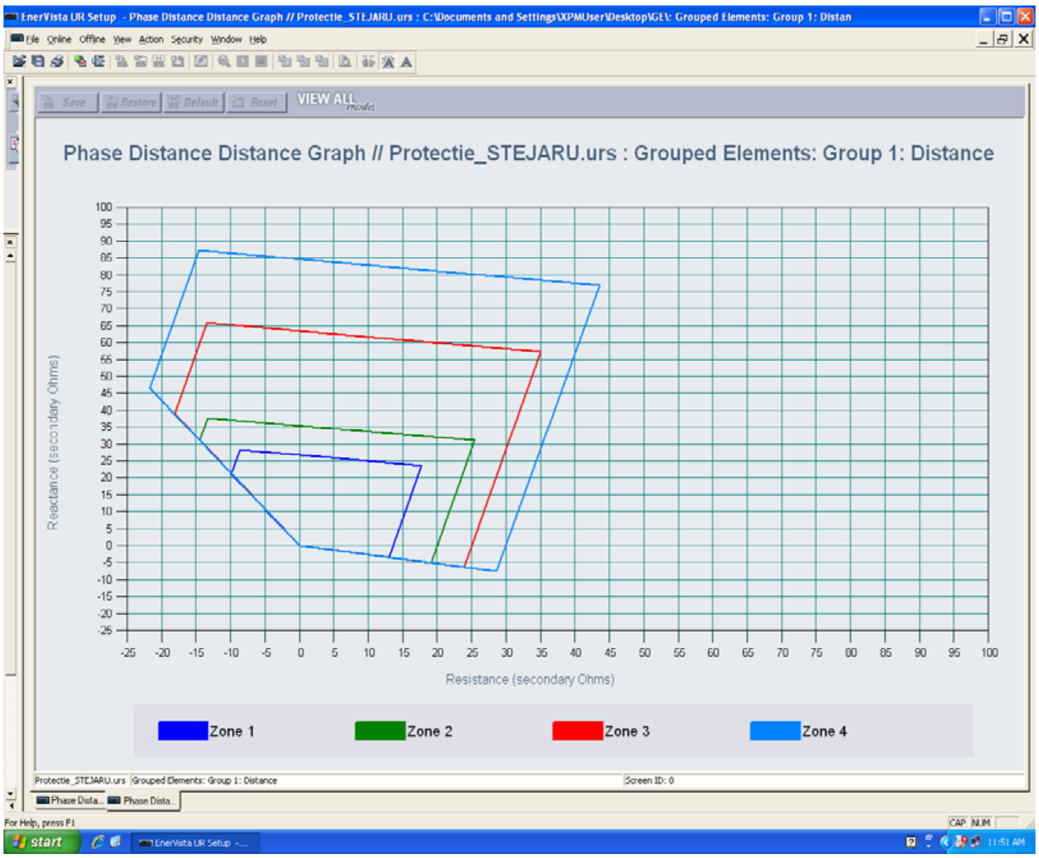
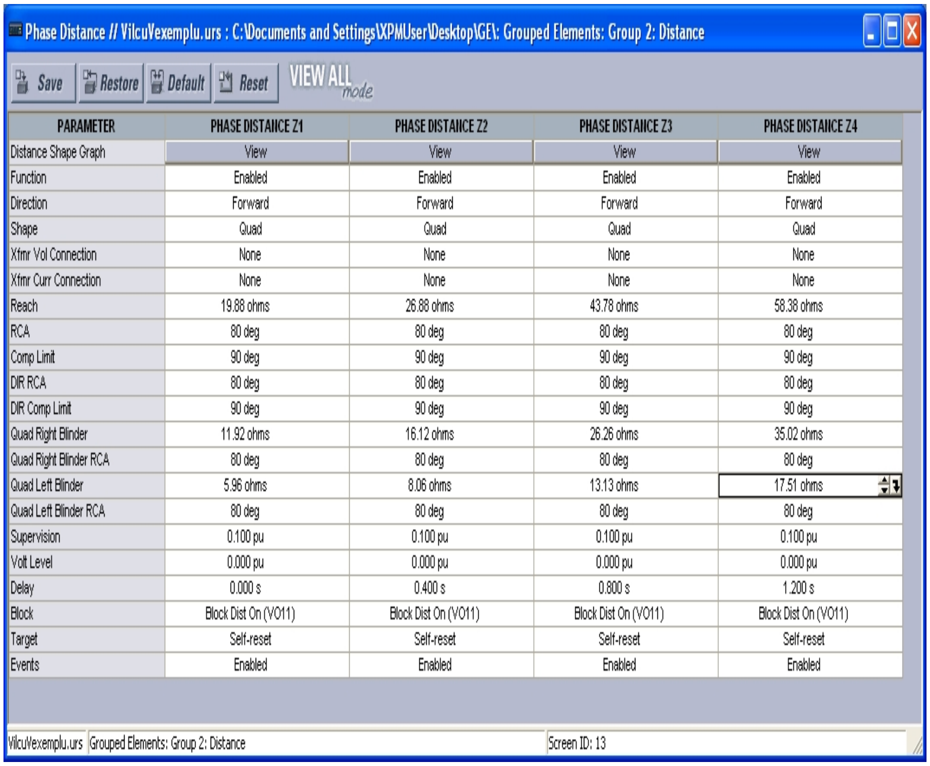


Fig. 5 - Capture Graph feature distance from v. 3.1 D60 relay settings set 1

Adjustments to the upper rungs of the distance protection is calculated by autotransformer considered the median plot who provide primary voltage transformation ratio of nominal rated versus secondary.

In fact, as I mentioned, autotransformers ensure permanent control voltage transformer by changing positions, very likely the occurrence of a fault does not lie outside of a nominal transformation ratio so it does not exactly match our assumptions for calculating.

Set 2 settings mean response desensitized to the corresponding ratio transformer autotransformer 231/121/10, 5 kV. Fig. 6 shows calculations were carried out considering AT plot 18.

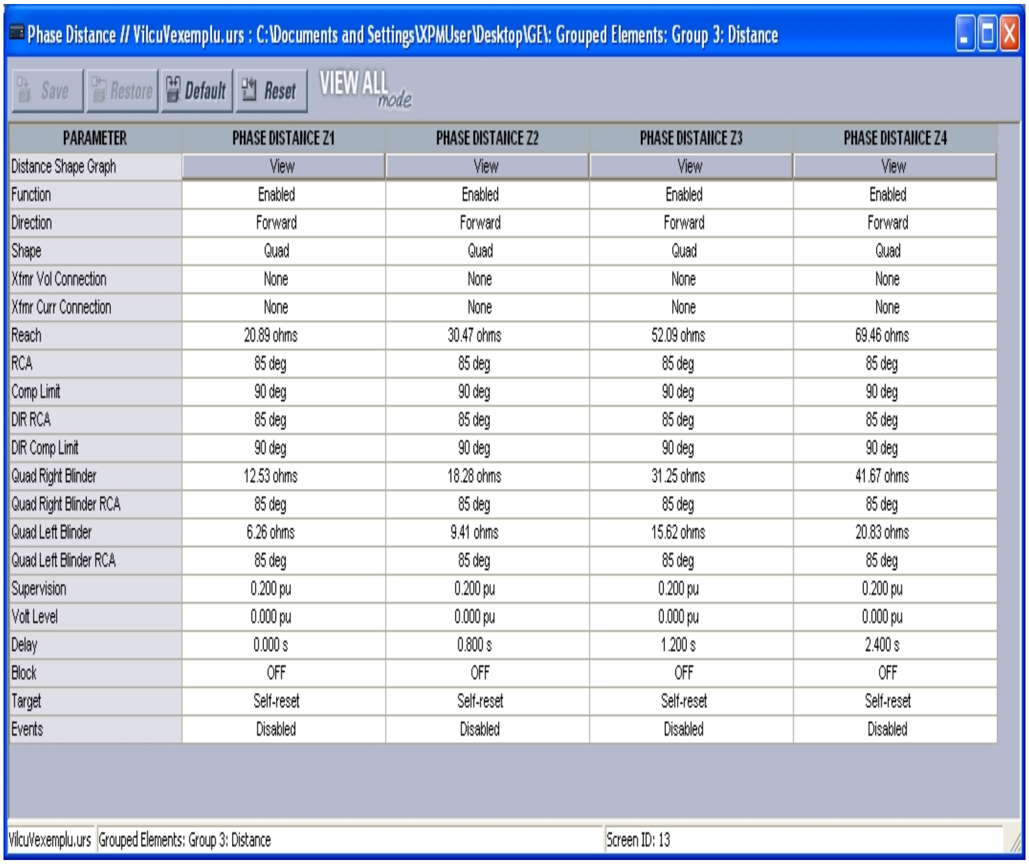


PARAMETER	PHASE DISTANCE Z1	PHASE DISTANCE Z2	PHASE DISTANCE Z3	PHASE DISTANCE Z4
Distance Shape Graph	View	View	View	View
Function	Enabled	Enabled	Enabled	Enabled
Direction	Forward	Forward	Forward	Forward
Shape	Quad	Quad	Quad	Quad
Xfmr Vol Connection	None	None	None	None
Xfmr Curr Connection	None	None	None	None
Reach	19.88 ohms	26.88 ohms	43.78 ohms	58.38 ohms
RCA	80 deg	80 deg	80 deg	80 deg
Comp Limit	90 deg	90 deg	90 deg	90 deg
DIR RCA	80 deg	80 deg	80 deg	80 deg
DIR Comp Limit	90 deg	90 deg	90 deg	90 deg
Quad Right Blinder	11.92 ohms	16.12 ohms	26.26 ohms	35.02 ohms
Quad Right Blinder RCA	80 deg	80 deg	80 deg	80 deg
Quad Left Blinder	5.96 ohms	8.06 ohms	13.13 ohms	17.51 ohms
Quad Left Blinder RCA	80 deg	80 deg	80 deg	80 deg
Supervision	0.100 pu	0.100 pu	0.100 pu	0.100 pu
Volt Level	0.000 pu	0.000 pu	0.000 pu	0.000 pu
Delay	0.000 s	0.400 s	0.800 s	1.200 s
Block	Block Dist On (VO11)	Block Dist On (VO11)	Block Dist On (VO11)	Block Dist On (VO11)
Target	Self-reset	Self-reset	Self-reset	Self-reset
Events	Enabled	Enabled	Enabled	Enabled

Fig. 6 - Capture of the listing D60 relay settings set 2 v. 3.1

All these changes in distance protection are to be selected from defects in low voltage network but also safe for defects in AT.

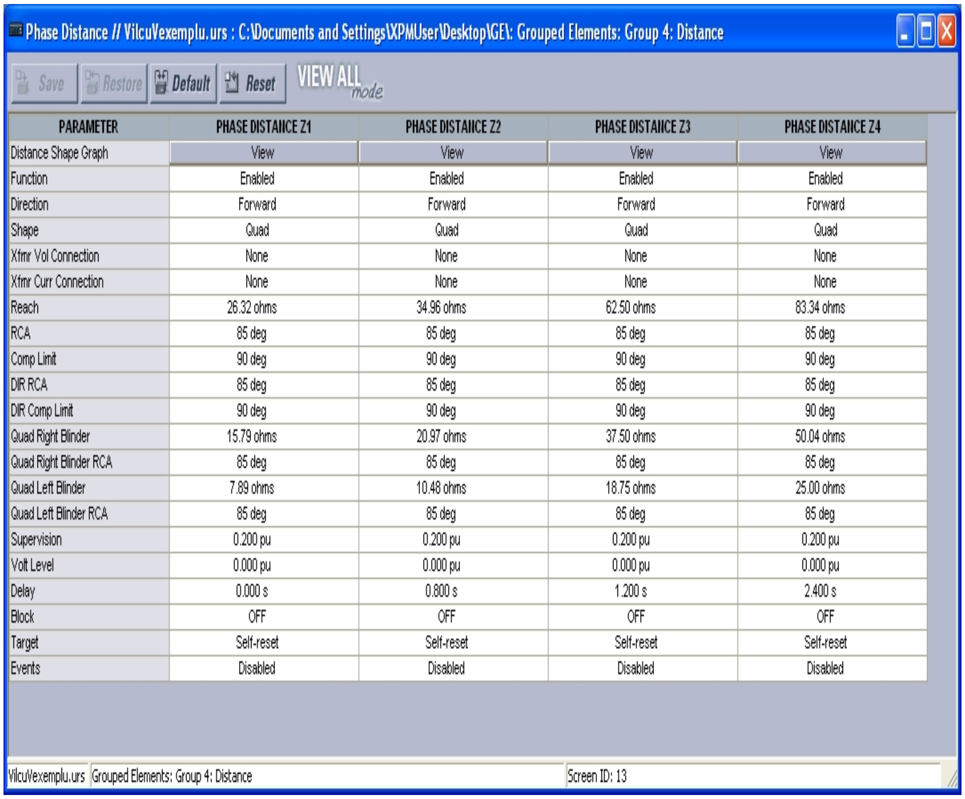
In Fig. 7 shows the set 3 settings mean response desensitized to the corresponding ratio transformer autotransformer 231/121/10, 5 kV considering the plot AT 9.



PARAMETER	PHASE DISTANCE Z1	PHASE DISTANCE Z2	PHASE DISTANCE Z3	PHASE DISTANCE Z4
Distance Shape Graph	View	View	View	View
Function	Enabled	Enabled	Enabled	Enabled
Direction	Forward	Forward	Forward	Forward
Shape	Quad	Quad	Quad	Quad
Xfmr Vol Connection	None	None	None	None
Xfmr Curr Connection	None	None	None	None
Reach	20.89 ohms	30.47 ohms	52.09 ohms	69.46 ohms
RCA	85 deg	85 deg	85 deg	85 deg
Comp Limit	90 deg	90 deg	90 deg	90 deg
DIR RCA	85 deg	85 deg	85 deg	85 deg
DIR Comp Limit	90 deg	90 deg	90 deg	90 deg
Quad Right Blinder	12.53 ohms	18.28 ohms	31.25 ohms	41.67 ohms
Quad Right Blinder RCA	85 deg	85 deg	85 deg	85 deg
Quad Left Blinder	6.26 ohms	9.41 ohms	15.62 ohms	20.83 ohms
Quad Left Blinder RCA	85 deg	85 deg	85 deg	85 deg
Supervision	0.200 pu	0.200 pu	0.200 pu	0.200 pu
Volt Level	0.000 pu	0.000 pu	0.000 pu	0.000 pu
Delay	0.000 s	0.800 s	1.200 s	2.400 s
Block	OFF	OFF	OFF	OFF
Target	Self-reset	Self-reset	Self-reset	Self-reset
Events	Disabled	Disabled	Disabled	Disabled

Fig. 7 - Capture the listing D60 relay settings set 3 v. 3.1

In Fig. 8 is shown set 4 settings mean response desensitized to the corresponding ratio transformer autotransformer 196,35/121/10,5 kV, considering AT in plot 1, with high reactance.



PARAMETER	PHASE DISTANCE Z1	PHASE DISTANCE Z2	PHASE DISTANCE Z3	PHASE DISTANCE Z4
Distance Shape Graph	View	View	View	View
Function	Enabled	Enabled	Enabled	Enabled
Direction	Forward	Forward	Forward	Forward
Shape	Quad	Quad	Quad	Quad
Xfmr Vol Connection	None	None	None	None
Xfmr Curr Connection	None	None	None	None
Reach	26.32 ohms	34.96 ohms	62.50 ohms	83.34 ohms
RCA	85 deg	85 deg	85 deg	85 deg
Comp Limit	90 deg	90 deg	90 deg	90 deg
DIR RCA	85 deg	85 deg	85 deg	85 deg
DIR Comp Limit	90 deg	90 deg	90 deg	90 deg
Quad Right Blinder	15.79 ohms	20.97 ohms	37.50 ohms	50.04 ohms
Quad Right Blinder RCA	85 deg	85 deg	85 deg	85 deg
Quad Left Blinder	7.89 ohms	10.48 ohms	18.75 ohms	25.00 ohms
Quad Left Blinder RCA	85 deg	85 deg	85 deg	85 deg
Supervision	0.200 pu	0.200 pu	0.200 pu	0.200 pu
Volt Level	0.000 pu	0.000 pu	0.000 pu	0.000 pu
Delay	0.000 s	0.800 s	1.200 s	2.400 s
Block	OFF	OFF	OFF	OFF
Target	Self-reset	Self-reset	Self-reset	Self-reset
Events	Disabled	Disabled	Disabled	Disabled

Fig. 8 Capture of the listing D60 relay settings set 4 v. 3.1

6. Conclusions

Autotransformers adjustable under load are a very important for electrical voltage control in a network node that changes its electrical parameters by adjusting the voltage and changing positions of permanent transformation.

Calculating adjustments to the upper rungs of the distance protection are considering the median plot of the autotransformer, the positions of tapings that provide primary voltage transformation ratio of nominal rated voltage versus secondary versus tertiary nominal voltage.

For distance protection, this way of calculating means a huge non-selectivity by modifying these parameters, what makes it likely that the occurrence of a fault does not lie outside of a nominal transformation ratio, therefore it does not exactly correspond to our assumptions for calculating these and is no longer in accordance with the facts.

By using several sets of settings in the same relay we may very well correct this situation because modern numerical relays have at least 4 sets of settings, which facilitates for the first time in Romania the usage of these sets by internal logic diagram relay track selective short-circuits both in the differential autotransformer and in its outer region.

In this way the distance protection can be about as selective as a longitudinal differential protection.

Surely, several sets of settings allow selectivity and absolute protection. Each set of adjustments presented in the article has its own characteristic defects working phase - phase and earth fault.

Changing the operation feature for each shift reaction corresponds to the increase / decrease of the tapings and it is arranged for selective protection with new settings as system parameters are set in four shots from the relay. This new approach to the protection philosophy allows changes / revisions to the technical standards for the transmission system.

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