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DIFFERENTIAL PROTECTION IN TRANSFORMER BLOCK IN KOSOVO B

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Abstract

Is presented a discussion of differential protection in general and in the case of power transformers for high voltage level and by analyzing concrete example in Kosovo B power plant.

INTRODUCTION

Differential protection is used for rapid detection of various errors that can occur at different voltage levels of energy transformers, as well as rotary machines as for instance motors, generators, short circuits and bus bars. Specifying the application of differential protection can be selected also from the way the parameterization of differential protection is done. In this way can be selected the optimal way of the differential protection and the object to be protected. Used differential protection for power transformers in two windings, three windings up to a five winding power transformers also the functionality of the differential protection depends on the configuration and settings of the configured protection, however only those parameters that are relevant and object depending should be placed in protection relay.

THE WORKING PRINCIPLE OF DIFFERENTIAL PROTECTION

Differential protection works on the principle of comparing currents, in the case of two winding power transformer currents should be compared from both sides, currents from the primary side and currents from the secondary side. Below with the Figure 1 is shown bonding scheme and working principle of differential protection.

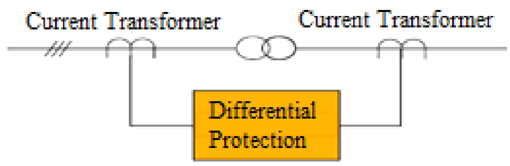


Fig.1 Two-Coil Transformer

Also is presented a schema for power three winding transformer and directions of currents is shown in Figure 2.

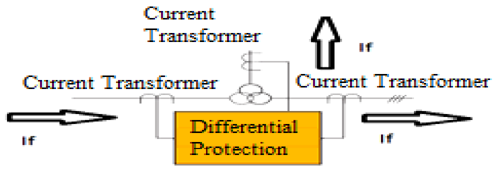


Fig.2 Differential Protection applied in Three-Coil Transformer

In Figure 2 are shown only relay circuits for a phase. During normal operation or in the case of defects out of both of current transformers, *if that* enters the device is equal to *if that* comes out of the device in all phases (neglecting small internal parasitical currents). In the base unit, secondary currents are equal to the current of the primary minus magnetization currents of current transformer.

In this case, the current which excites the relay is the difference between existing currents and magnetization currents. With same types of power transformers, this current will be small in normal load. Differential relays are altered every time above this maximum value during normal operation. If the fault eventuates between the two of current transformers, one or more current on the left side will suddenly increase, while the currents on the right side could be either reduced or increased and flow in the opposite direction. In any case, the total current will flow through the relay winding, causing its reaction.

If we own ideal current transformers, an over current relay on the "differential" can be allocated to respond with speed sensitive. However, in practice the two current transformer will not provide exactly the same current of the secondary same as the primary current. Changes may be due to vibrations of production, differences in loads on the secondary caused by unequal lengths of conductors of relay connections and uneven loads on the secondary of current Transformers. While in normal conditions differential currents are low, when short circuit currents flow of an external fault it can become significant. An over current relay should be accorded above the maximum error current that can be expected during an external fault.

Percentage differential relays solve this problem without sacrificing sensitivity. Blocking windings receive electricity of the transformer secondary and make the relay insensitive on large currents external defects.

Electricity required for the operation of the relay increases with amplitude-size of external fault current. Figure 3 show the different curves family of blocking currents for action currents, which apply differential relay.

Where from here can be defined areas of action and inaction as in Figure 2.a.

When transformers changing automatically winding position for adjustment for example, under-load, there is a small but tolerable differential current which circulates in the relay, differential relays therefore designed with the possibility of allocation. Proper selection and application of current transformers used in differential protections schemes are critical to their right action.

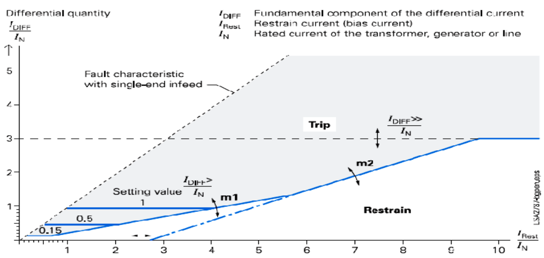


Figure 3 3-phase short-circuit fault characteristic

When applying differential protection should be given a separate importance to it if the power transformer is realized with high impedance, impedance with small rezistenvë or through peteresenit. In Figure 3 we present realization schema with high impedance differential protection.

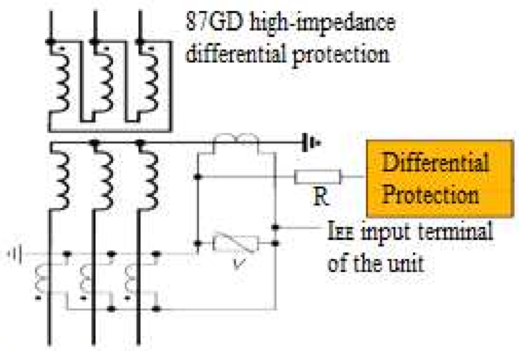
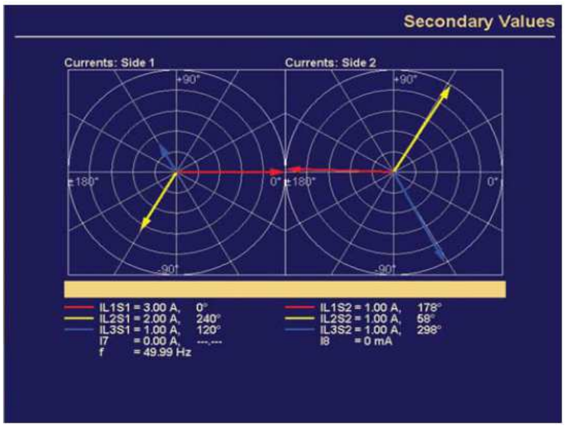


Fig.3 Differential protection with high-impedance

MATCHING SECONDARY CURRENTS PHASE

In addition to matching the size of the secondary currents values of current transformers in the case of windings connection of the power transformer under different vector groups i.e. YNd11 must match the phase of secondary currents on both sides of the power transformer. In this case phase removal between the primary currents and secondary of the power transformer has a difference of 30 ®.

In addition the problem of eliminating the null ranking component is raised, because in the case of star connection one power transformer winding and which is earthed. Short circuit currents with land outside the protected area which exists only on the side of the star of the power transformer, on the differential relay that is a differential current that causes wrong actions of relay. To eliminate this is required that intermediate transformers with homologous vector groups to change places, i.e. the triangle connect to the side of the star and star group on the side of the triangle of power transformer windings.



Figures below are presented multifunctional defenses which serve to implement differential protection. On the basis of developments in technology have also protections developed that are used for power system protection. Multifunctional protections that are used today for differential protection have the opportunity to realize other protections such as: over current protection, protection of short-circuits between phases, protection of earth short-circuits and other protections. Today's opportunities are significantly better.

Figure 4 transformer protections for different types of energy transformers: two winding, three winding and five winding manufactured by SIEMENS.

Is presented the implementation of differential protection in energy transformer 24/400 [kV] in Block B2 in Kosovo B.

Below presents the single line diagram of the block transformer and generator T2 in Kosovo B. The figure shows the form of the implementation of differential protection for power transformer 400 [MVA] voltage level 24/400 [kV]. Power transformer is two winding and differential protection is realized comparing primary and secondary side currents. There are also technical data of the power transformer and the data for CMTR on the Primary and Secondary side.

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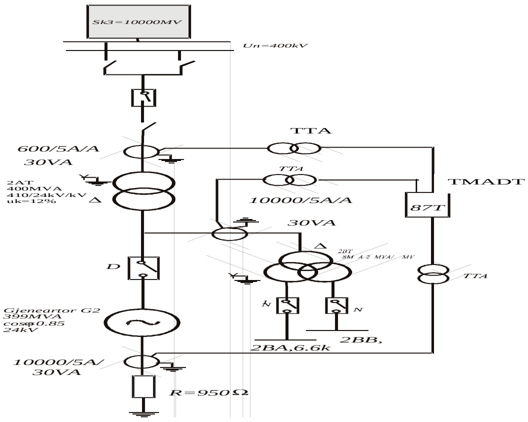


Nominal data of block generator-transformer:

Generator:

$Un = 24[kV];$

$In = 9650[A];$

$Sn = 399[MVA]$

Measuring current transformers from side primary**:**

$CT{:}\frac{10000}{5[A]};30[VA];5P15;$

Intermediate Transformers (TTA)

$Proportion \quad 1{:}1000;$

$Regulation = 0.96;$

$In = 5[mA];$

$connection\ of\ CMTR\ Y - Y$

Transformer AT2:

$U'/U" = 24/410[kV];$

$Inp = 9650[A];$

$Ins = 560[A];\ Dy5 -\ connection$

Secondary side of Current measuring Transformers:

$CT{:}\frac{600}{5[A]};30[VA];5P15;I = 4.67[A]$

Intermediate Transformers (TTA):

$1{:}1732\ Ratio;$

$Adjustment = 0.94;$

$In = 5[mA];\ Y - D - connection$

Transformer AT2:

$U'/U" = 24/6.6/6.6[kV];$

$Inp = 9650[A];\ Dyy - connection.$

Primary side of Current measuring Transformers:

$CT{:}\frac{10000}{5[A]};30[VA];5P15;4.82[A]$

Intermediate Transformers (TTA):

$Proportion \quad : 1{:}1000\ ;$

$Adjustment = 0.96;$

$In = 5[mA]; Y - Y - connection$

Case I review:

Currents from side primary to transformer AT2 are on these values:

$Irn = 9650[A];$

$Isn = 9650[A];$

$Itn9650[A]$

$and\ the\ side\ secondary\ currents\ are:$

$Irn = 560[A];$

$Isn = 560[A];$

$Itn = 560[A]\ and$

$In = 0$

Calculate the differential currents while the transformer is under nominal load:

$Un = 24[kV]$

$$Current\ Transformer: \frac{10000}{5[A]}$$

Estimating the transformation quotient:

$$Nct = \frac{10000}{5} =$$

2000,

whilst currents on side 24[kV] that streams through the relay shall be:

$$I = \frac{9650}{2000} = 4.825[A] \gg I = 4.825 * \frac{1}{1000}$$

$$= 4.825[mA]$$

On the side 400[kV] currents will be:

$$CMTR - et\ Nct = \frac{600}{5} = 120\ ;$$

$$I = \frac{560}{120} = 4.66[A] * \frac{1}{1.732 * 0.94}$$

$$= 2.865[mA] \geq\geq I = 1.73 * 2.865$$

$$= 4.958[mA]$$

$$\Delta I = I400kv - I24kv = 4.958 - 4.825$$

$$= 0.133[mA]\ results\ from\ this \gg \frac{\Delta I}{In}$$

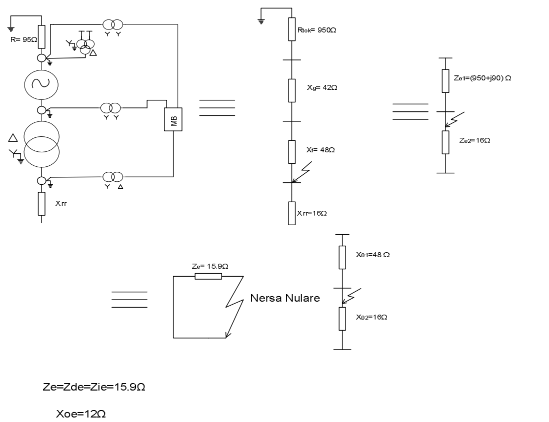
$$= \frac{0.133}{5} = 0.0266 \gg \Delta I = 0.0266 * In$$

$$= 2.6\%In$$

From this we conclude that with the power transformer nominal load and data's of CMTR-s presented above the relay will not act, but will be in permitted boundaries.

THE CASE WHEN WE HAVE SINGLE-PHASE SHORT CIRCUITS IN THE PROTECTED -II AREA

To analyze the problem when there are short circuits within the protected zone of the differential protection, you should first analyze the single phase short circuit within the area; according to schematics below estimate also the single phase short circuit:



From above schema's we find quickly the following:

$$X_g = \frac{x \circ U^2}{100 \circ S_n} \circ m^2 = 42\Omega$$

$$X_T = \frac{u_k \circ U^2}{100 \circ S_n} = 48\Omega$$

$$X_{RR} = \frac{U_n^2}{S_k} = 16\,\Omega$$

Symmetric components of currents are:

$$I_o = I_d = I_i = I_o = \frac{U_f}{j(X_{de} + X_{ie} + X_{oe})} =$$

$$\frac{400}{\sqrt{3}} \frac{1}{(15.9+15.9+12)} = \frac{231}{43.8} = -5.27kA$$

Fault phase currents are:

$$I_a = 3I_d = 3 \circ (-5.27kA)$$

$$I_b = 0$$

$$I_c = 0$$

Null components:

$$I_{ol} = \frac{X_{10}}{X_{02} + X_{01}} I_0 = 0.75 \circ 5270 = 3952A$$

Direct and inverse components

$$I_d = I_i = \frac{X_{1e}}{X_{e2} + X_{e1}} I_0 = 0.98 \circ 5270 = 5164A$$

Currents on the line phases on the secondary side of the transformer 400kV (protected zone are):

$$I_{RL} = I_{ol} + I_{dl} + I_{il} = 14.281kA$$

$$I_{SL} = I_{ol} + a^2 I_{dl} + aI_{il} = 72.6kA$$

$$I_{TL} = I_{ol} + aI_{dl} + a^2 I_{il} = 7.26kA$$

Namely, the current that passes through the current transformer for relay provisioning are presented in Figure3b

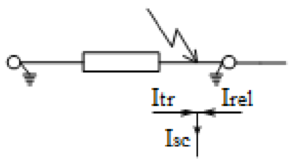


Figure 3b.

Irel=Isc -Itr

Currents from the primary side of the transformer AT2 (400kV) have these values:

I_{Rn}=9650A ;

I_{Sn}=9650A;

I_{Tn}=9650A

Whilst currents on the secondary side are:

I_R=14.28[kA];

I_S=7.26 [kA];

I_T=7.26 [kA];

$I_N \neq 0$

Than for single phase short circuits in phase R with earth when IR=14.28kA we estimate the currents that flow the differential protection: Un =24kV;

Current transformer quotient: 10000/5 A $N_{CT} = \frac{10000}{5} = 2000$ whilst currents on the sode 24kV on the relay are IR=$\frac{9650}{2000}$ =4.825A$\Rightarrow$ IR=4.825$\circ\frac{1}{1000}$=4.825mA

Thus on the secondary side of the transformer (400kV) the currents are

Un=400kV ;

Current transformer: $N_{CT} = \frac{600}{5} = 120$

IR=$\frac{14280}{120}$=119A$\Rightarrow$I=119 $\circ\frac{1}{1732\circ 0.94}$ =73.09mA$\Rightarrow$I=$\sqrt{3}$ I=1.73$\circ$73.09=126.44mA

$\Delta I_R = I_{24kv} - I_{400kv} =$ I 4.825-126.44

I=121.6mA

$\frac{\Delta I}{I_n} = \frac{121.6}{5} = 24.32 \Rightarrow \Delta I = 24.32 \circ I_n \Rightarrow$

ΔI Reg=2432$\%$ I_n

On the basis of this we ascertain that this phase is the cause to the response of the protection because that protection is at the boundaries ($\Delta I = 32\% \ I_n$). This can be seen by the diagram shown in Figure3c

CASE WHERE THERE ARE THREE PHASE SH.C OUTSIDE THE PROTECTED AREA (CLOSE TO 400 KVA TRANSFORMERS).

The phase short circuit currents are calculated:

$$I_{3f} = \frac{U_f}{X_d} = \frac{400}{\sqrt{3}\circ 15.9} = 14.52kA$$

In this case the nominal currents on the primary side of the transformer is In = 9560, while on the secondary is I+n = 560A.

Currents circulating on the relay:

I=$\frac{9650}{2000}$=4.825A$\Rightarrow$I=4.825$\circ\frac{1}{1000}$=4.825mA

While on the secondary side of the transformer (400kV) the currents is

Un=400kV;

Current transformer $N_{CT} = \frac{600}{5} = 120$

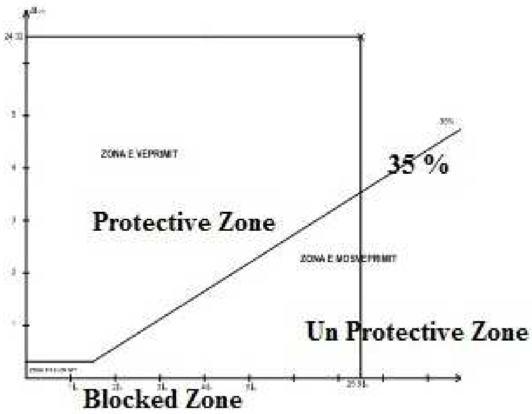
I=$\frac{560}{120}$=4.666A$\Rightarrow$I=4.666 $\circ\frac{1}{1732\circ 0.94}$

=2.865mA$\Rightarrow$I=$\sqrt{3}$ I=1.73$\circ$2.865=4.958mA

$\Delta I = I_{400kv} - I_{24kv}$ =4.958-4.825=0.133mA

$$\frac{\Delta I}{I_n} = \frac{0.133}{5} = 0.0266 \Rightarrow \Delta I = 0.0266 \circ I_n \Rightarrow$$

ΔI =2.6 % I_n



In this case running current in current transformers to feed the relays is the nominal current, so the short circuit current outside the zone does not affect the operation of the relay

This is also shown in the Figure 4.

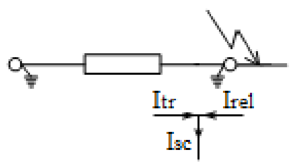
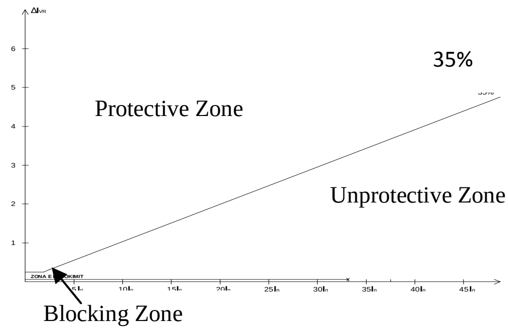


Figure 4a

Based on this we find that the protection is within the allowed boundaries as the reaction rate is in the limits of (ΔI = 32 % I_n).

This is shown in the following Figure 4b



It is known from the theory of relay protections during normal working regime through differential winding flows a small stream, which is a result of the electricity magnetization of energy transformer, errors on CMTR. This current is a small percentage compared to the nominal current.

Differential protection must not operate during short circuits outside the protective zone ie short circuits to the network, during various transitional processes such as: running the power transformer in an offload mode, with discharge currents if the connection is done from the high voltage side high values reach (5-10) I_n or if the connection is done on the low voltage side

(10-20) I_n. It is known that the transformer differential relays have low sensitivity because they are fed by current transformers of various types and with different transformation ratio.

Differential protection should be disaccorded short external circuits, increasing the voltage and running of the transformers. For short external circuits through differential relay windings the imbalanced currents can circulate on huge value. This current is resulted by the CMTR errors. E.g. if the voltage regulator (tap changer) is in a position of on the finite position +20% and when short circuit currents on the network have the value $I_{lsh} = 10I_n$ then across differential winding flows the $\Delta I=2xI_{vep\ mb.}$ For this case, the protection should not operate. In this way that the action current not to be higher than the operational current differential protection, the protection is to be disaccorded from these currents. This is achieved by setting relay restriction winding.

For various reasons on the network, are over voltages produced in short times. During the rise of voltage (1.2-1.3) U_n magnetisation currents increase (10-100) I_{on} manifested by the increase of currents in the relay and wrong action of protection. To eliminate this becomes the protection is disaccorded from short-term risings on the voltage transformers using the fifth magnetization current harmonic that is resulted due to the high induction in the magnetic core.

CONCLUSION

When analyzing the concrete example of differential Protection TC. Kosova B-block transformer T2, we conclude that the adjustment of the protection is to the extent permitted by IEC standards, protection adjustment may also be in the 25% * In, but for reasons that the power transformer is with a long-time exploitation, magnetization current parameters are higher and other parameters.

Whilst analyzing the differential protection on the concrete example TC. Kosova B, is necessary that the self expenditures power transformer is provided with differential protection, so that in the future the complete block is prevented from problems, possible problem that may rise with the self expenditures transformers.

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