IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 16, Issue 5 Ser. I (Sep. – Oct. 2021), PP 10-15
www.iosrjournals.org

Method of choosing Knee Point Voltage (KPV) of phase and neutral current transformers for Low Impedance Restricted Earth Fault Relay (REF relay) operations to avoid saturation

AUTHOR

***Abstract**: It is known that even for a far end phase fault the REF relays may false operate due to saturation of the phase due to spill over of the harmonic currents. This article describes a method of choosing the Kpv(knee point voltage) of both the phase and neutral current CTs so that the differential current may not cause false operation due to saturation of the current transformers either at phase or neutral end of the power transformers.*

***Keywords**: REF Settings, Power Transformer, Low Impedance REF Principle, Current Transformer, Interposing Auxiliary CTs, Knee point voltage*

Date of Submission: 03-09-2021 Date of Acceptance: 16-09-2021

Abbreviations : CTR1 Phase end CT ratio
CTR2 Neutral end CT ratio

RCT1 Phase CT secondary resistance

RL1 –Phase side lead resistance

RCT2 –Neutral CT secondary resistance

RL2 –Neutral side lead resistance

X/R –Reactance to resistance ratio of the of the fault circuit (Power Transformer)

L/R –time constant of the fault circuit

Z –Impedance of the fault circuit

Ia, Ib, Ic –Phase CT primary currents
In–NeutralCTprimary current

I. Introduction:

In the case of low impedance REF relays it is known that the CT secondary sum of phase currents and neutral current are separately fed into the intelligent numerical relay which mainly estimates the differential current and causes operation of the relay only in the case of internal faults. In the case of external faults the differential current becomes equal to zero because the sum of phase current (which gives rise to the zero sequence current) and neutral current become the same and there is no differential current. Even if the neutral CT ratio is different a multiplication ratio is used in the relay to make itssecondary current equal to the sum of phasecurrents(secondary)to compensatefor the difference in the CT ratio from that of the phase value. Even though this is done there is a danger of the low impedance REF relays mal operation if the CTs at either end saturate due to wrong selection of the knee point voltage. The phase CTS can produce spill zero sequence current into the relay and cause a differential current operation of the low impedance REF relay even though there is no earth fault if the Kpv of the CTs is not adequately chosen. It is therefore important that for the magnitude of fault currents involved the CT knee point voltages at both the phase and neutral ends are properly chosen to avoid the saturation of the CTs. In the case of high impedance REF relays even if the CTs saturate at phase or neutral end the setting of the relay can be chosen high enough with care so that for external faults the relay does not operate. This is an advantage of the high impedance REF principle because of its high stability for external faults. In the case of low impedance REF principle the traditional advantage has been to choose a different CT ratio at the neutral from the phase side. But in the case of low impedance REF principle it is important to avoid the saturation of CTs to avoid maloperation by suitably selecting its parameters.

In this article a method has been proposed to select the Kpv(knee point voltage) of the CTs from first principles both at the phase and neutral ends to avoid saturation of the same.

CT parameter(knee point voltage)selection principle

Generally the earth fault current is higher than three phase fault current and hence the same is chosen for CT (Kpv) design. The phase CTs are situated close to the relay as compared to the neutral CT and hence its lead resistance ignored.

It should be kept in mind that the REF relays operate in about 40 milliseconds (Instantaneous response time) considered and hence the asymmetry of current waveform cannot be ignored in choosing a higher value of the knee point voltage. For evaluating the knee point voltage in this article therefore the detailed time response of the earth fault current has been done and the instantaneous peak current from the time response has been chosenwithin the operating time of the relay to arrive at the highest value of the Kpv forthe CT from a knowledge of the X/R ratio of the transformer and the earth fault current and the % impedance of the transformer. The following application example will make the principle clear.

Application example:For the purpose of this example a 11kv / 433 Volt, 2000 Kva power transformer is considered with a 5% impedance and an R/X ratio of 7. The other parameters considered are:

CTR1(phase) :3200/1A

CTR2 (neutral) : 1600 /1A

RCT1: = 10ohms.

RL1 = (neglected on phase side)

RCT2 = 5.5 ohms

RL2 = 2 ohms (lead resistanceto relayon neutral side)

The symmetrical fault current can be estimated as =2000/0.05 = 40000 Kva = 53336 amps on LV side. (assuming HV side as infinite bus)

The time response of current can be given by the following relationship (including AC and decaying DC components)

I (Inst)Primary=(E. $\sqrt{2}$/Z). { Sin(wt –phi) + Sin (phi). exp(-R/L.t) }-----(1)

I (inst) secondary of CT on phase side = I(inst) Primary / 3200

I (inst) secondary of CT on neutral side = I(inst) Primary / 1600
where R/X = cos(phi) of the circuit= 1/7 = 0.142857

From which

Phi = 1.427449radians

Sin(phi) = 0.989743

R/L = 44.877 seconds.

L/R =0.022 second

Mathematical basis for choosing the Kpv value: This is chosen as the maximum valueof the actual secondary CT voltage attainedin the operating time of the relay. Hence inthe following analysis in this paper the Kpvvalue is chosen as the following :
Kpv(recommended) = Max instantaneoussecondary current (within relay operatingtime) x (RCT + RL)

Table 1 indicates the time response(amps)of the secondary currenton phaseCTsof power transformer as per above equation (1). Now the actual value of instantaneous peak value into the relay depends on the value of the operating time of the REF relay. Assuming an operating time of 40 milliseconds it is prudent to select a peak value of current slightly less than 40 milliseconds. Hence from Table 1 it is seen that at about 30 milliseconds the peak value reached is 29.57 amps secondary current after which the secondary current starts decreasing. Hence the design value for the Kpv calculation can be chosen as 30 amps secondary current for phase CTs and 60 amps for neutral CTs.Expressing this as a factor K (ratio) of the secondary RMS current of 16.66 amps (i.e, 53336/3200 amps) , this works outto 29.57/16.66 = 1.78 times

Now there are different values of this ratio suggested to be chosen as per literatures available. They are the following:

A)2 as per traditional guidelines.

B) 2 x ROOT (2)(which means a K factor of 2.728)as per some authors but this factor is a value as well known for the initial maximum value of the total

current envelope even though the initial instantaneous value of secondary amps is zero. It takes a few milliseconds for the secondary current to reach the peak valuewhich is less than 2xROOT(2) times the initial peak value of the envelope. This time to reach the instantaneous first peak in the present case is actually seen to be about half a cycle in our case (0.009 sec), i.e,. 38.8 amps(i.e. a K value of38.8/16.66= 2.33 only). Hence this high value of 2.33 cannot be chosen for Kpv design as it is excessive.

C) 1 as per AREVA guidelines. But this is empirical and is on the lowersideas revealed by the above calculations which indicatesthat a factor of 1.78 can be chosen as the correct value for Kpv design.

Therefore in our present case Kpv value for phase side CTs works out to 1.78x16.66x(RCT1)

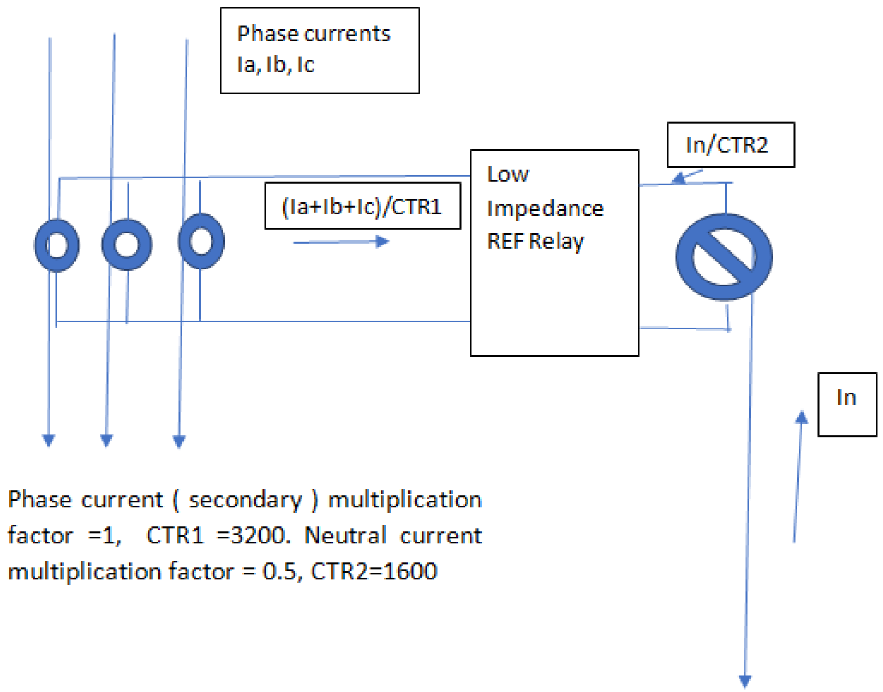
= 1.78 x16.66 x 10 = 295.7 Vols = say 300 Volts

and the Kpv value for neutral side CTs works out to 2x1.78x16.66xX(RCT2)

= 2x 1.78x16.66x(5.5+2) = 444.8 Volts = Say 450 Volts

As per what is indicated by cases A, B, C and comparing with rigorous calculations as indicated in this paper a factor of 2 can be safely chosen on the conservative side if detailed calculations are not warranted and not required to be done.

FIGURE 1



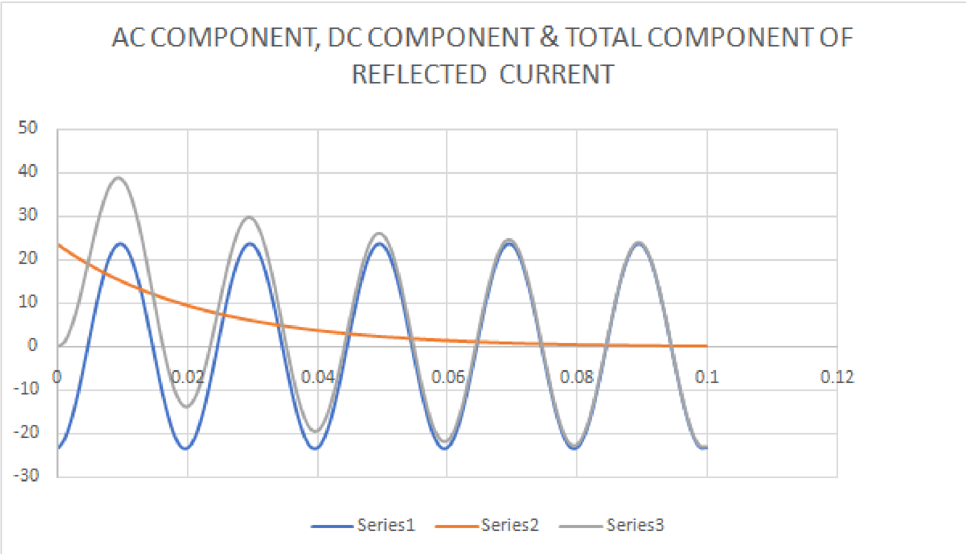


FIGURE 2 (Short circuit response)

TIME (Secs)	Secondary amps(total
0	0
0.001	1.1585
0.002	4.432
0.003	9.4032
0.004	15.489
0.005(Quarter cycle , 5 milli secs)	22.0076
0.006	28.234
0.007	33.477
0.008	37.14
0.009	38.8

0.01 (Half cycle , 10 milli secs)	38.22
0.011	35.38
0.012	30.51
0.013	24.0
0.014	16.45
0.015(15 milli secs, three quarters of cycle)	8.53
0.016	0.965
0.017	-5.56
0.018	-10.45
0.019	-13.28
0.02 (One cycle , 20 milli secs)	-13.82
0.021	-12.0566
0.022	-8.2
0.023	-2.67
0.024	3.94
0.025 (1.25 cycle , 25 milli secs)	10.96
0.026	17.67
0.027	23.38
0.028	27.49
0.029	29.57
0.03(1.5 cycle, 30 milli secs)	29.399
0.031	26.95
0.032	22.44
0.033	16.29
0.034	9.079
0.035(35 milli secs ,1.75 cycle)	1.482

TABLE 1

Note : Since the neutral CT ratio is 1600/1A the secondary CT current for the same will be twice the above values in Table 1

II. Conclusions

This article has attempted to furnish a detailed calculationmethodfor determining the Knee Point voltage for low impedance REF CT applications of power transformers. It has highlighted the relative merits of the various methods of applying the Kpv calculations forlow impedanceREF CTs for power transformers. Since the operating time of relay is less than 40 milliseconds and the Kpv value depends of the X/R of the fault circuit, it is worthwhile to apply a detailed method as indicated in this article to determine the knee point voltage of the CTs instead of relying on approximate thumb rules for the same because the results of the various methods can vary widely depending on the parameters of the CT and circuit constants.Unlike high impedance REF method where an inherent high stability is offered, the saturation of CTs can make the low impedance REF relay maloperate and hence more accurate methods are necessitated to specify their Kpvs correctly so that CT saturation and relay maloperation can be avoided.

References

[1]. Alsthom Network Protection and Automation Guide (Protective Relays Measurement and Control), May 2011 edn. Micom 30 series, REF Protection application guide, Issue B1, Alsthom

[2]. A comparison between high impedance and low impedance REF Transformer protection by Casper Labuschagne and Izak Vander Merwe, pp. 1–9. Eskom Enterprises and Schweitzer Engg (2005–2007)

[3]. D. Robertson (ed.), Power System Protection Reference Manual, Reyrolle Protection, Chapter 6 (Orient Press)

[4]. Performance of REF Protection scheme in the presence of CT remanence, ed. by K.J.A. Jallil, A.H.A. Bakae, W.N. Wan Mahadi, Hanif—Power Energy Conference, 2008 IEEE Second International

[5]. Application Notes MICOM series P63x/UK AP/A54 MiCOM P631, P632, P633, P634
[6]. Cahier technique no. 158-Calculation of short-circuit currents, Schneider electric
[7]. Current Transformer Sizing & Saturation calculation with Transient Performance Analysis of CT Using ATP Software : International Journal of advanced Research in Electrical, Electronics and Instrumentation engineering Vol 4, Issue 5, May 2015 . By Sachin Tiwary and Aditya Pandey
[8]. CT Saturation in Industrial Applications –Analysis and Application Guidelines.
[9]. ---Document No GET 8501 Bogdan Kasztenny, Manager, Protection & Systems Engineering, GE Multilin Jeff Mazereeuw, Global Technology Manager, GE Multilin Kent Jones, Technology Manager, GE Multilin -Instrument Transformers Inc

XXXXXX. "Method of choosing Knee Point Voltage (KPV) of phase and neutral current transformers for Low Impedance Restricted Earth Fault Relay (REF relay) operations to avoid saturation." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE),* 16(5), (2021): pp. 10-15.