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Ensuring Relay Protection Device Reliability by Setting Value and Time Delay Verification (10Kv Motor Differential Current Protection)

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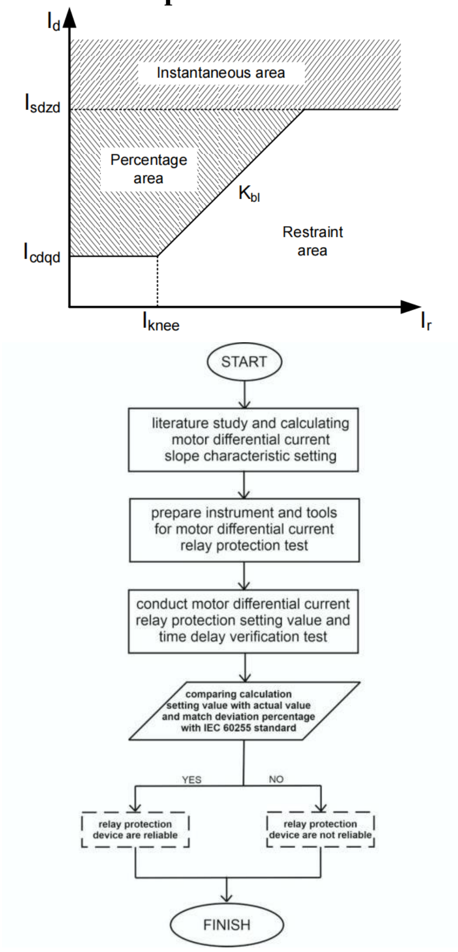
Graphical abstract



Abstract

Protection relay devices are very important in the electrical system where they act as voltage breakers when there is a disturbance in the electrical system so that electrical equipment and those connected to it are not damaged. Based on the IEC 60255 standard, protection relay devices are required to be reliable, fast, and selective so that the electrical system is protected from disturbances and works properly without miss-operation. The standard tolerance for the verification value deviation is not more than 5% of the setting value, this refers to the IEC 60255 standard. This journal explains the testing of setting valuesand time delays on protection relay devices that focus on differential current protection. The results of this test can be concluded whether the protection relay is still suitable for use or not with a standard tolerance deviation of ≤5%.

Keywords: *Relay, Protection, Verification, Differential,Reliable*

Abstrak

device relai proteksi sangatlah penting di dalam sistem listrik di mana bertindak sebagai pemutus tegangan saat terjadi gangguan pada sistem listrik agar equipment listrik dan yang terhubung dengannya tidak mengalami kerusakan. Berdasarkan pada standar IEC 60255 device relai proteksi diharuskan handal, cepat, dan selektif agar sistem listrik ter-lindungi dari gangguan dan bekerja secara benar tidak terjadi mal-operasi. Adapun standard toleransi deviasi nilai verifikasi tidak lebih 5% dari nilai setting, hal ini mengacu pada standard IEC 60255. Jurnal ini menjelaskan pengetesan setting value dan time delay pada device relai proteksi yang berfokus pada proteksi differential current. Hasil dari pengetesan ini dapat kita simpul-kan apakah relai proteksi masih layak dipakai atau tidak dengan standard toleransi deviasi ≤5%.

Kata kunci: Relai, Proteksi, Verifikasi, Differential, Handal

1. INTRODUCTION

Based on the IEC 60255 standard, protection relay devices are required to be reliable, fast, and selective so that the electrical system is protected from disturbances and works properly without miss-operation. The standard tolerance for the verification value deviation is not more than 5% of the setting value.[1]

It is necessary to carry out a setting value test by verifying the deviation of the actual value and the setting value. In general, relay testing is carried out every 2 years. This is stated in the PT PLN protection and control maintenance manual.[2]This journal will focus on testing the slop and time delay characteristics of the differential current relay. The device to be tested is a numerical relay for 10kv motor protection, NARI brand with the model is PCS-9641.

1.1 Differential Current Protection

Differential current protection is a protection that is specifically used to protect a particular electrical device, because the electrical device has a fairly high economic value, this protection is used. The working principle of this protection uses Kirchoff's first law where the input and output currents of the electrical device are relatively the same.[3]

Differential protection for motors requires two CT inputs, one on the terminal side and the other on the neutral side. The CT on the terminal side acts to measure the current at the motor input and the CT on the neutral side acts to measure the current at the motor output， So we can see that the area protected by differential protection is the area limited by the CT terminal and CT neutral. In the protection relay, the calculation of the difference between the terminal side and the neutral side will be carried out, so different polarities are required from the CT terminal side and the CT neutral side.[4]

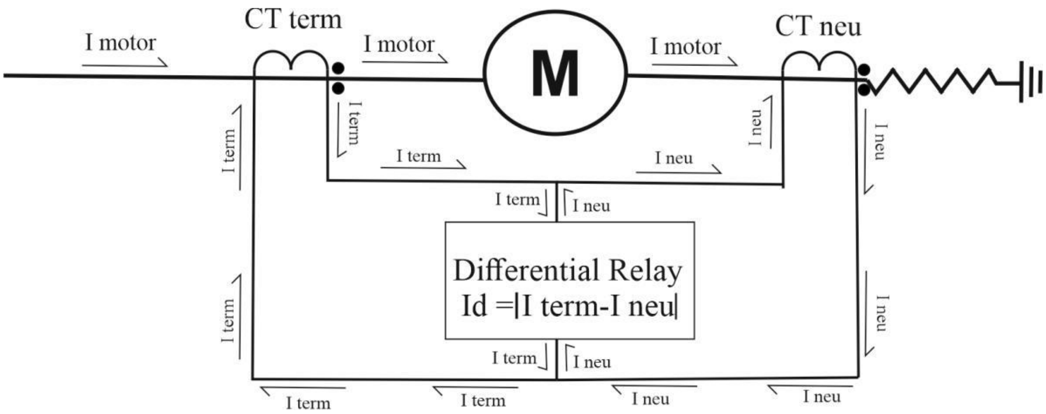


Figure 1. Differential Protection Scheme for Single Phase Motor

Each protection device has its own curve characteristics and calculation formula for the NARI PCS-9641 device which has the following curve:

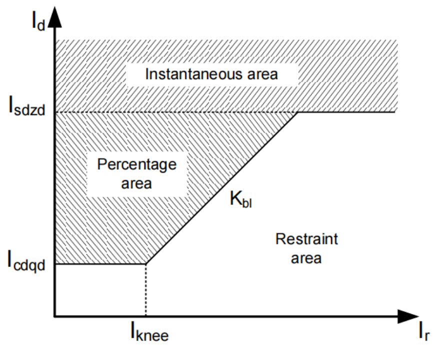


Figure 2. NARI PCS-9641 Differential Protection Operation Curve Characteristics

Where:

K_{bl} : is the restraint coefficient, the setting [87M.Slope]

I_{cdqd} : is the pickup setting of differential protection, the setting [87M.I_Biased]

I_{sdzd} : is the current setting of instantaneous differential protection, the setting [87M.I_Inst]

I_{knee} : is the current setting of knee point, the setting[87M.I_Knee]

I_d : is the differential current, which value equal to "$|I_T + I_N|$"

I_r : is the restraint current, which value equal to "$|I_T - I_N|/2$"
can be written in the following equation:

$$|I_T + I_N| > I_{cdqd} \quad \text{if} \quad |I_T - I_N|/2 \leq I_{knee} \tag{1}$$

$$|I_T + I_N| - I_{cdqd} > K_{bl} \times (|I_T - I_N|/2 - I_{knee}) \quad \text{if} \quad |I_T - I_N|/2 > I_{knee} \tag{2}$$

Where:
K_{bl} : is the restraint coefficient, the setting [87M.Slope]
I_{cdqd} : is the pickup setting of differential protection, the setting [87M.I_Biased]
I_{knee} : is the current setting of knee point, the setting[87M.I_Knee]
I_T : is the current of terminal side
I_N : is the current of neutral point side

The protection relay will be active when the Id and Ir value points are in the shaded area, even if only one phase.[5]As previously stated, in the NARI PCS-9641 relay, the Id value is obtained from the absolute value of the sum of the current at the terminal and the current at the neutral point, so a CT input with the opposite polarity is required. If the CT input from the terminal side is polarity S_1, then the CT input from the neutral side must be polarity S_2. So in this test we have to adjust the phase angle current on the terminal and neutral sides so that they are 180 degrees opposite each other.[6]

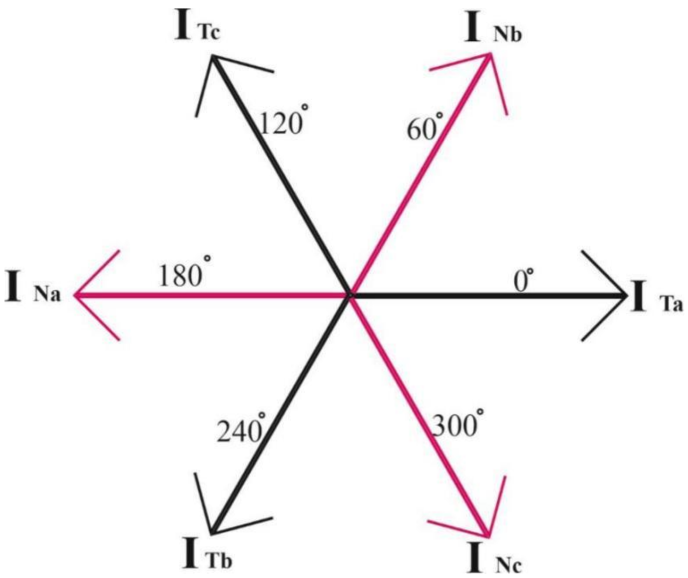


Figure 3. Phase Angle Illustration $I_{Ta,b,c}$ is CT Current from the Terminal Side; $I_{Na,b,c}$ is CT Current from the Neutral Side

The function of the Ir value parameter itself in differential protection is to select the activation of differential protection only in the area limited by the 2 CTs, This is illustrated in the differential protection characteristic curve where if the fault happen on the outside of the 2 CTs Id value is must be near 0, and also at the motor start time it will occur inrush current when induction motor need to generate emf for the first time, so Id will be on the slope section and the large Id it will not be active if it is accompanied by a large Ir value. because the purpose of differential protection is to protect the targeted electrical equipment, not to protect the entire electrical system.

2. METHODOLOGY

The methodology in this writing uses literature studies and experiments on protection equipment using relay testers, calculating the current that must be injected and analyzing the deviation of the actual value with the IEC 60255 standard.

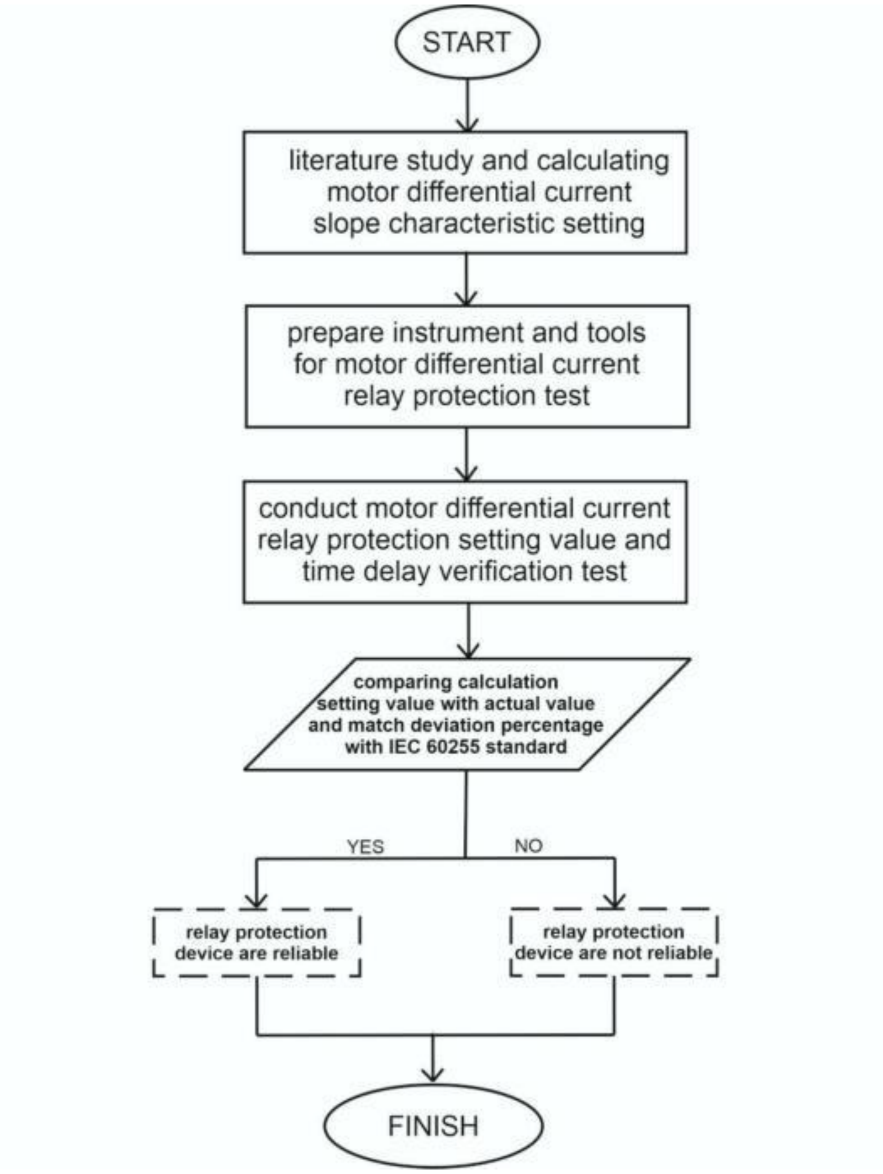


Figure 4. Flow Chart of the Research

3. RESULT AND DISCUSSION

In this chapter, the testing of the curve characteristics on differential protection and time delay testing will be discussed one by one, and will be divided into 4 sub-chapters, namely:

1. Pickup current test on differential protection
2. Slope bias gradient test on differential protection
3. Instantaneous current test on differential protection
4. Time delay test on differential protection

In this relay test, we will use secondary values. The settings & parameters that need to be known are as follows:

Tabel 1. Setting Value NARI PCS-9641 Motor Differential Protection

Parameter	Setting value
Motor rated Current (A)	0,62
87M.I_Inst current setting of instantaneous(A)(I_{sdzd})	6,2
87M.I_Biased current setting of pickup(A) (I_{cdqd})	0,3
87M.I_Knee current setting of knee point(Ie)(I_{knee})	0,7Ie = 0,434A
87M.Slope slope coefficient (K_{bl})	0,5
Time delay (s)	0

3.1 Pickup Current Test on Differential Protection

In this sub-chapter we will testing the pick-up settings. we can see in the curve image, the verified setting section

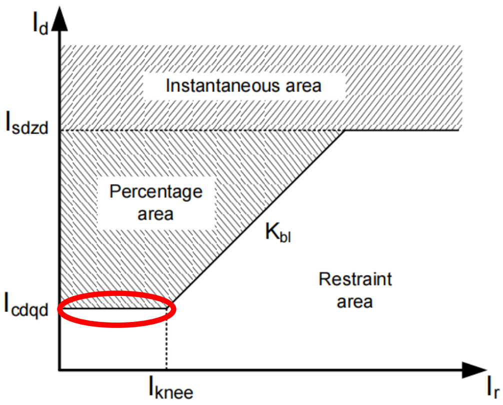


Figure 5. Tested Settings Marked with Red Circle

Before testing, we must first do the calculation. From the image, the pickup setting curve applies if the Ir value is less than I_{knee}. In the I_{knee} setting, the value is 0.7 of the rated current, so the I_{knee} is

$$I_{knee} = 0{,}7 \text{ x } Ie = 0{,}7 \text{ x } 0{,}62 = 0{,}434A \quad (3)$$

From the calculations, the value is found to be 0.434A, so to test the pickup setting, the Ir value cannot be more than 0.434A. In the pick up test we try to enter an Id value 0,3A and .$|I_T + I_N|$= Id so $|I_T + I_N|$ = 0,3 we make the current at the terminal value 0 so that the Ir value is below the I_{knee} value (Ir ≤ 0,434A) so $|0 + I_N|$ = 0,3, $|I_N|$ = 0,3-0, $|I_N|$ = 0,3. I_N has an absolute value because basically the phase angle between the terminal and neutral is opposite, under normal circumstances we assume the value at the terminal is positive (0˚) and at the neutral is negative (180˚) so I_N = -0,3. Need to calculate Ir value to confirm is not more than I_{knee} value, $|I_T - I_N|/2$ = Ir so $|0 - (-0{,}3)|/2$ = Ir, 0,3/2 =Ir, so Ir = 0,15A. We tested the current injection of 0A on the terminal side and 0,3A on the neutral side, then the test results were as follows:

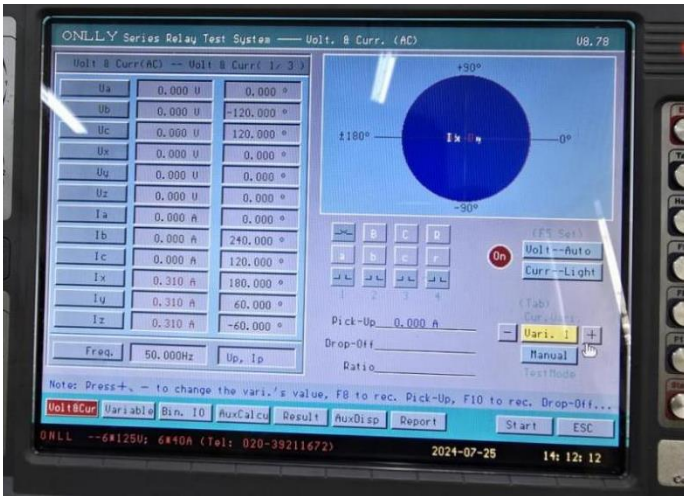


Figure 6. Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side

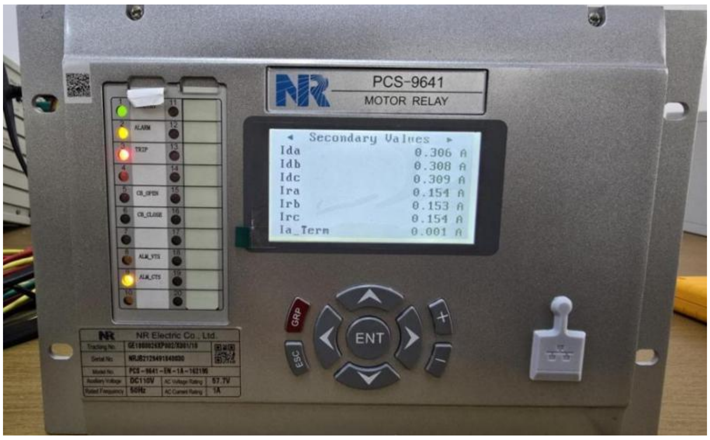


Figure 7. Relay Protection Device Id& Ir Sampling and Trip Action LED Lit

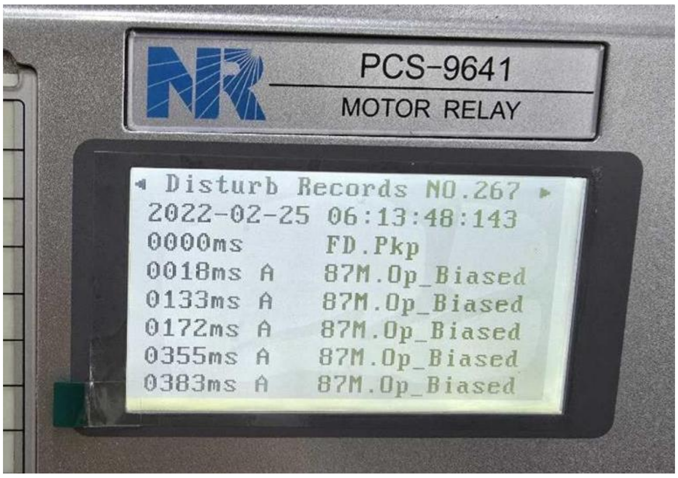


Figure 8. Relay Protection Device Action Information

The actual current value injected is different from the calculated value because when the current is injected the calculated value, the protection device is not active, it is active when the value is increased by 0,01A. then the percentage difference between the actual value in the sampling and the setting value must be calculated and compared with the IEC 60255 standard, namely the difference must not be more than 5%.

$$\frac{0{,}309A-0{,}3A}{0{,}3A} \times 100\% = 0{,}009A/0{,}3A \times 100\% = 3\% \qquad (4)$$

The percentage difference value is found to be no more than the IEC standard, then the differential pickup setting in this protection device still meets the standard.

3.2 Slope Bias Gradient Test on Differential Protection

In this sub-chapter we will testing the slope bias gradient settings. we can see in the curve image, the verified setting section

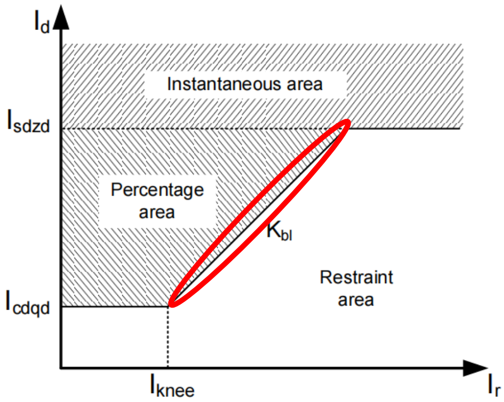


Figure 9. Tested Settings Marked with Red Circle

for conduct a slope test first determine 2 points on the slope line that should be, we assume the first point with Id = 0.3A and Ir = 0.434A is exactly at the I_{knee} point, and second point we assume Id = 1A and for second point Ir we calculate first from the formula, because the slope is begin from the knee point slope setting is 0,5 so the formula for Ir when Id = 1A is ($Id-I_{cdqd}$) = K_{bl} x ($Ir-I_{knee}$) so (1-0,3) = 0,5 x (Ir-0,434) then 0,7/0,5 = Ir-0,434 then 1,4+0,434 = Ir so Ir = 1,834 A, after get the 2 point on the slope line try to inject the current according to the point. For the first point calculate I_T and I_N that we need inject:

$|I_T + I_N| =$ Id and $|I_T - I_N|/2$ = Ir so $|I_T + I_N| = 0{,}3$ and $|I_T - I_N|/2 = 0{,}434$ then $|I_T - I_N| = 0{,}434 \text{ x } 2$ so $|I_T - I_N| = 0{,}868$ then make elimination operation ($|I_T + I_N| = 0{,}3$) - ($|I_T - I_N| = 0{,}868$) so $2I_N$ = -0,568 then I_N = -0,284 the negative sign mean opposite polarity (180˚) then enter the I_N value in any equation we enter it in the Id equation $|I_T + I_N| =$ Id then $|I_T + (-0{,}284)| = 0{,}3$ then I_T = 0,3+0,284 so I_T = 0,584, we already get the terminal current and neutral current continue inject the current using relay tester. the test results were as follows:

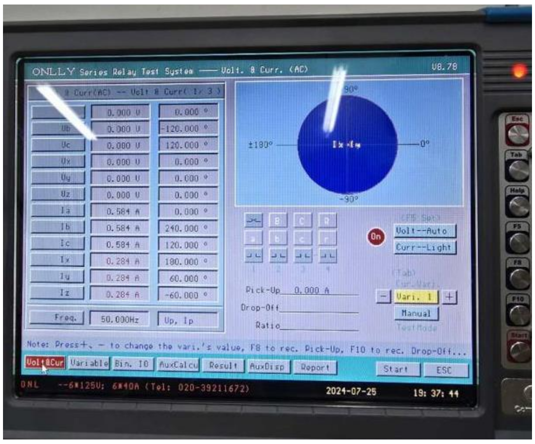


Figure 10. Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side

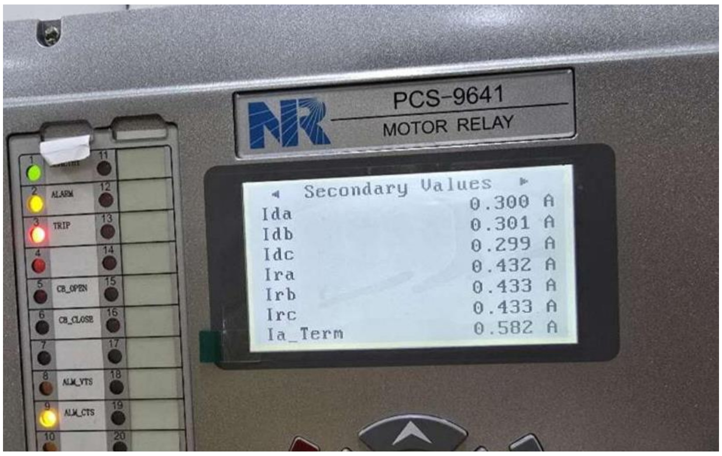


Figure 11. Relay Protection Device Id& Ir Sampling and Trip Action LED Lit

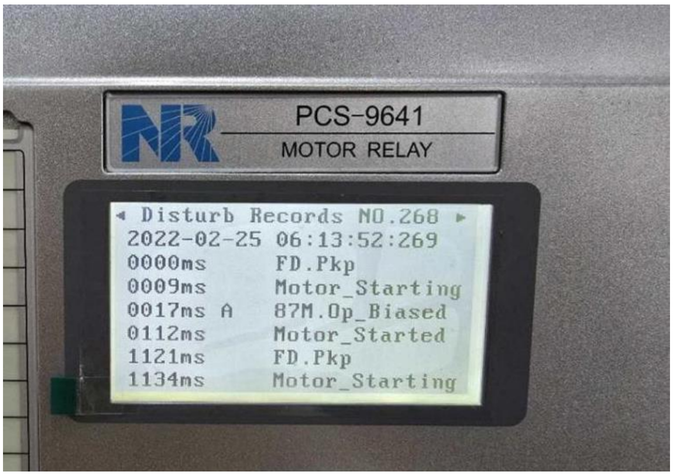


Figure 12. Relay Protection Device Action Information

For the first point already confirm it's make differential protection active, continue to the second point, first we calculate the I_T and I_N that we need inject. We already assume the second point is Id=1 and Ir=1,834 then calculate I_T and I_N that we need inject:

$|I_T + I_N| =$ Id and $|I_T - I_N|/2$ = Ir so $|I_T + I_N| = 1$ and

$|I_T - I_N|/2$ = 1,834 then $|I_T - I_N|$ = 1,834 x 2 so $|I_T - I_N|$ = 3,668 then make elimination operation ($|I_T + I_N| = 1$) - ($|I_T - I_N|$ = 3,668) so $2I_N$ = -2,668 then I_N = -1,334 the negative sign mean opposite polarity (180˚) then enter the I_N value in any equation we enter it in the Id equation $|I_T + I_N| =$ Id then $|I_T + (-1{,}334)| = 1$ then I_T = 1+1,334 so I_T = 2,334, we already get the terminal current and neutral current continue inject the current using relay tester. Because there's some deviation in the slope and in the sampling the protection device didn't active so we adjust the terminal and neutral current and we get the active current as follow:

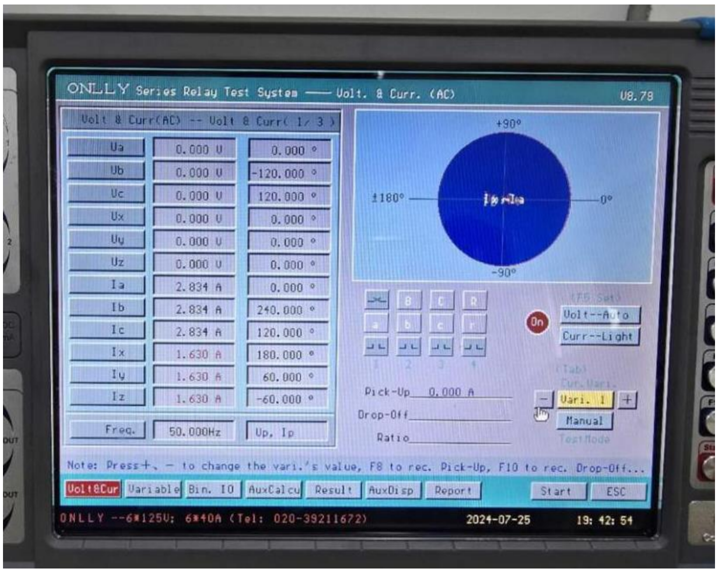


Figure 13. Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side

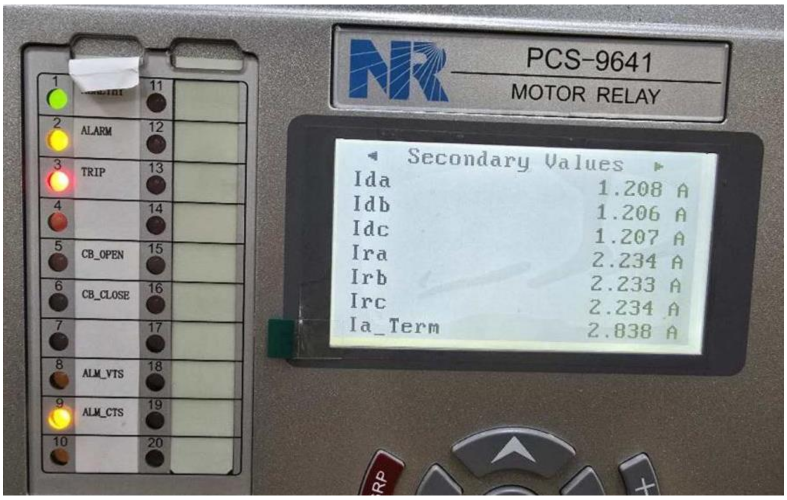


Figure 14. Relay Protection Device Id& Ir Sampling and Trip Action LED Lit

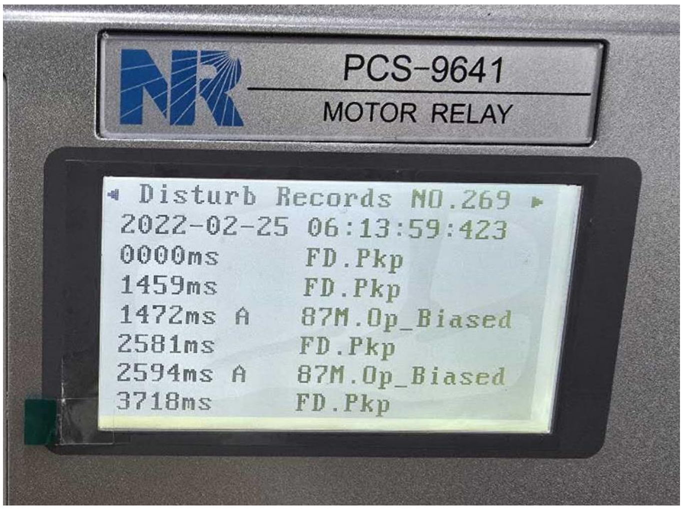


Figure 15. Relay Protection Device Action Information

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Then calculate the actual slope coefficient we use the Id and Ir from the highest value device sampling for the first point Id=0,301 and Ir=0,433 and for the second point Id=1,208 and Ir=2,234, then calculate slope coefficient using this equation:

$$\frac{Id2-Id1}{Ir2-Ir1} = Kbl \tag{5}$$

So $\frac{1{,}208-0{,}301}{2{,}234-0{,}433} = Kbl$ then $\frac{0{,}907}{1{,}801} = Kbl$ so K_{bl} = 0,5036 then the percentage difference between the slope coefficient actual value in the sampling and the setting value must be calculated and compared with the IEC 60255 standard, namely the difference must not be more than 5%.

$$\frac{0{,}5036A-0{,}5A}{0{,}5A} \text{ x } 100\% = 0{,}0036A/0{,}5A \text{ x } 100\% = 0{,}72\% \tag{6}$$

The percentage difference value is found to be no more than the IEC standard, then the differential slope coefficient setting in this protection device still meets the standard.

3.3 Instantaneous Current Test on Differential Protection

In this sub-chapter we will testing the slope bias gradient settings. we can see in the curve image, the verified setting section

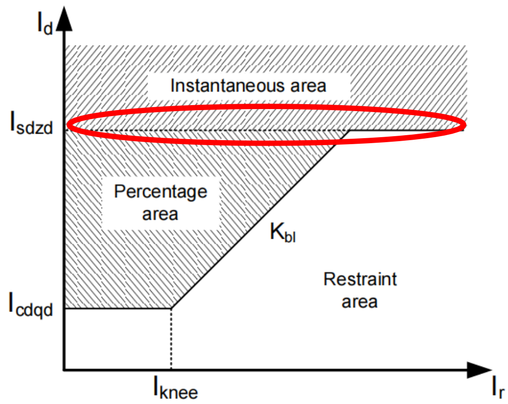

Figure 16. Tested Settings Marked with Red Circle

Because Instantaneous current test just need Id ≥6,2A so we inject the I_T and I_N difference 6.2, we inject 0A in the terminal and 6,2A in the neutral. the test results were as follows:

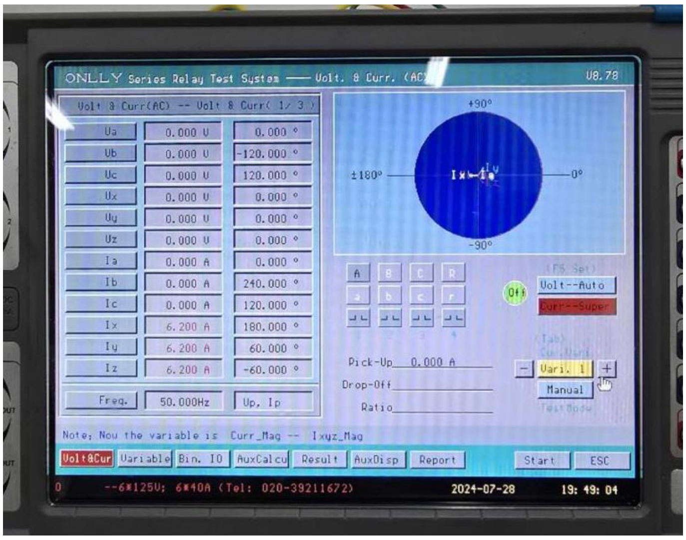

Figure 17. Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side

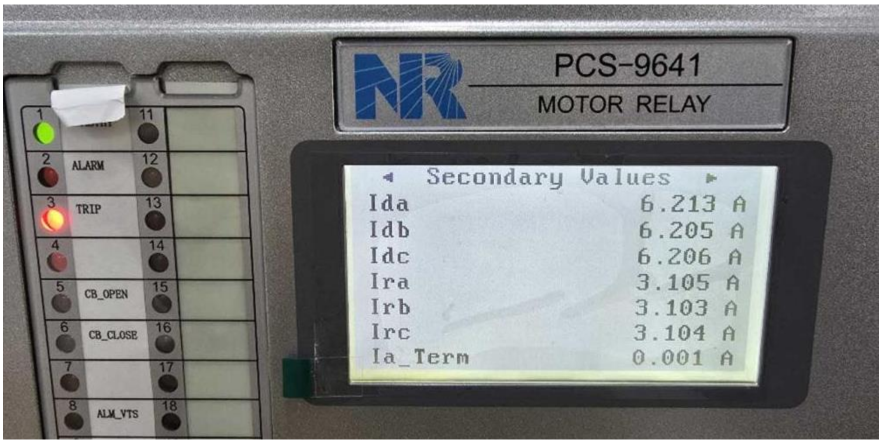

Figure 18. Relay Protection Device Id& Ir Sampling and Trip Action LED Lit

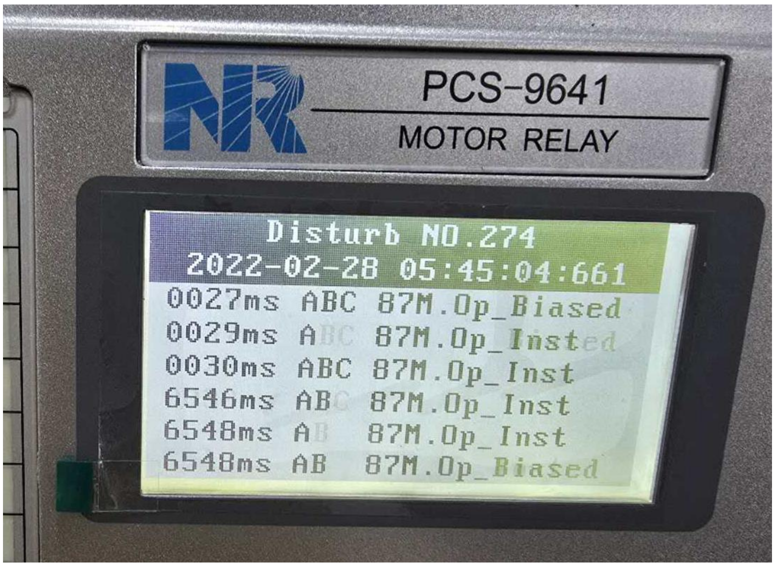

Figure 19. Relay Protection Device Action Information

then the percentage difference between the actual value in the sampling and the setting value must be calculated and compared with the IEC 60255 standard, namely the difference must not be more than 5%.

$$\frac{6{,}213A - 6{,}2A}{6{,}2A} \text{ x } 100\% = 0{,}013A/6{,}2A \text{ x } 100\% = 0{,}2\% \quad (7)$$

The percentage difference value is found to be no more than the IEC standard, then the differential pickup setting in this protection device still meets the standard.

3.4 Time Delay Test on Differential Protection

Because time delay test just need differential protection active and use the binary output signal to measure time delay so we inject 2 state condition, first state when there's no have any fault so we just inject 0A current in the both side and for the second state need fault condition so we inject the I_T and I_N difference 1, we inject 1A in the terminal and 0A in the neutral. the test results were as follows:

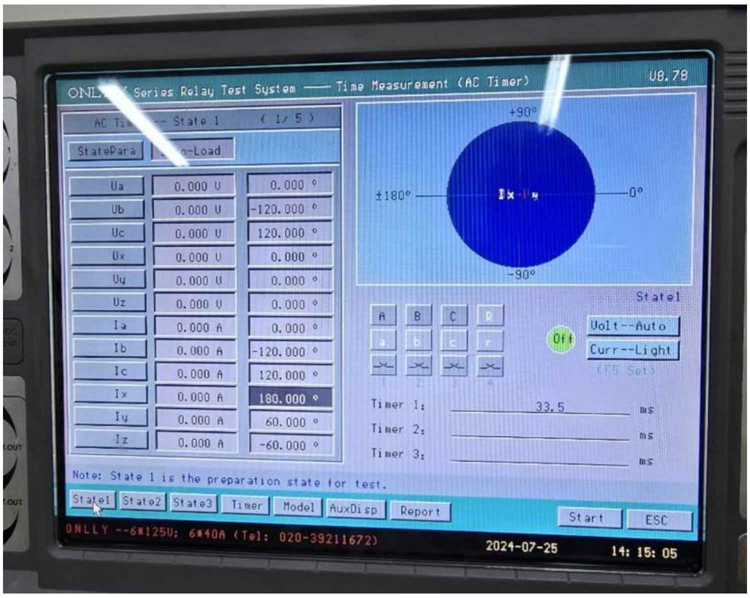

Figure 20. First State Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side

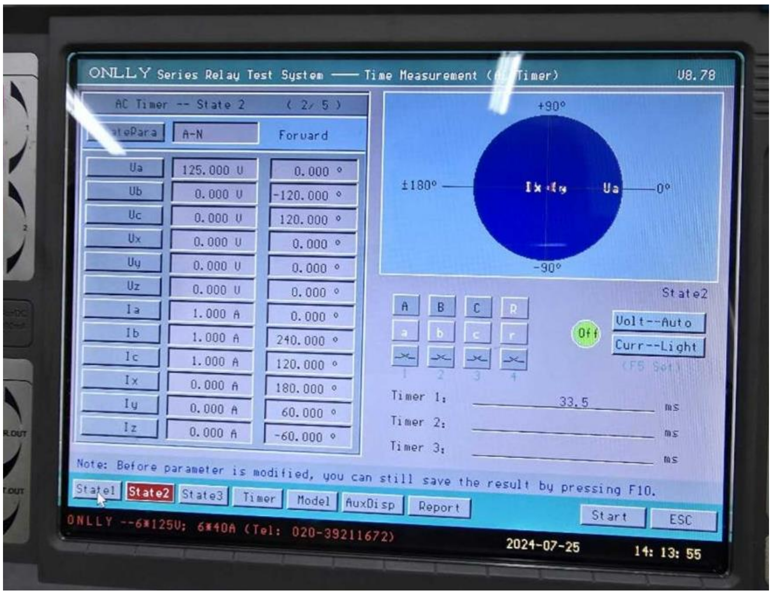

Figure 21. Second State Relay Tester Display on Current Injection Process $I_{a,b,c}$ is Current on the Terminal Side $I_{x,y,z}$ is Current on the Neutral Side Actual Time Delay is 33.5ms

For differential protection time delay standard from IEC60255 must less than 40ms and in this test the time delay is 33,5ms so time delay for this protection device is meets the standard

4. CONCLUSION

From the relay test, verification, and comparison with the IEC 60255 standard we get conclusion that Differential protection Pickup current test meets the standard, Differential protection slope bias gradient test meets the standard, Differential protection instantaneous current test meets the standard cause the difference actual value and setting value is less than 5% according IEC 60255, and than Differential protection time delay test meets the standard cause the difference actual value and setting value is less than 40ms according IEC 60255. Because all differential protection setting are meets the standard, so the protection device are reliable for differential current protection scheme.

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