

VAMP 255

Feeder and motor manager

Testing manual

Table of Contents

| | |
|---|-----------|
| 1. General | 5 |
| 1.1. Safety issues | 5 |
| 1.2. Testing equipment | 6 |
| 2. Pre-inspection procedures | 7 |
| 3. Adapting to local frequency and scaling | 11 |
| 4. Overcurrent protection stages testing | 14 |
| 4.1. Overcurrent stage $I > (50/51)$ | 14 |
| 4.1.1. Trip level test | 14 |
| 4.1.2. Operation time test (definite time) | 15 |
| 4.1.3. Operation time test (inverse time) | 15 |
| 4.2. Directional overcurrent stage $I_{dir} > (67)$ | 19 |
| 4.2.1. Trip level test | 20 |
| 4.2.2. Operation time test | 22 |
| 5. Earth fault protection stages testing | 23 |
| 5.1. Earth fault stage $I_0 > (50N/51N)$ | 23 |
| 5.1.1. Trip level test | 23 |
| 5.1.2. Operation time test | 24 |
| 5.2. Directional earth fault stage $I_{0\phi} > (67N)$ | 24 |
| 5.2.1. Trip level test in sector mode | 25 |
| 5.2.2. Trip level test in resistive and capacitive mode | 27 |
| 5.2.3. Operation time test | 28 |
| 6. Voltage protection stages testing | 29 |
| 6.1. Residual voltage protection $U_0 > (59N)$ | 29 |
| 6.1.1. Trip level test | 29 |
| 6.1.2. Operation delay test | 30 |
| 6.2. Overvoltage protection $U > (59)$ | 30 |
| 6.2.1. Trip level test | 31 |
| 6.2.2. Operation time test | 31 |
| 6.3. Undervoltage protection $U < (27)$ | 32 |
| 6.3.1. Trip level test | 33 |
| 6.3.2. Operation time test | 34 |
| 7. Frequency protection stages testing | 35 |
| 7.1. Overfrequency protection $f > (81H)$ | 35 |
| 7.1.1. Trip level test | 35 |
| 7.1.2. Operation time test | 36 |
| 7.2. Underfrequency protection $f < (81L)$ | 37 |
| 7.2.1. Trip level test | 37 |
| 7.2.2. Operation time test | 37 |
| 8. Other protection stages | 38 |
| 8.1. Auto-reclose function (79) | 38 |
| 8.2. Current unbalance protection (46) | 40 |
| 8.2.1. Trip level test | 41 |
| 8.2.2. Operation time test | 41 |
| 8.3. Thermal protection stage $T > (49)$ | 41 |
| 8.3.1. Trip level and operation time test | 42 |

| | |
|--|-----------|
| 8.4. Reverse power and underpower protection stage P> (32) | 43 |
| 8.4.1. Trip level test | 44 |
| 8.4.2. Operation time test | 44 |
| 8.5. Undercurrent protection stage I< (37) | 45 |
| 8.5.1. Trip level test | 45 |
| 8.5.2. Operation time test | 46 |
| 8.6. Arc fault protection stage ArcI> (50ARC) | 46 |
| 8.6.1. Operation time test | 47 |
| 9. Motor protection stages | 48 |
| 9.1. Stall protection I _{ST} > (48) | 48 |
| 9.1.1. Operation time test | 48 |
| 9.2. Phase reversal / incorrect phase sequence protection I ₂ >> (47) | 49 |
| 9.2.1. Operation time test | 49 |
| 10. Reference information | 50 |

1. General

This guide describes simple procedures to test the protection stages of feeder and motor manager relay VAMP 255 with firmware version 6.23.

Test personnel must be familiar with general relay practices and safety precautions to avoid personal injuries or equipment damage.

1.1. Safety issues

Before testing this or any product please read this chapter carefully.

This chapter describes safety precautions recommended when commissioning Vamp protection relays. Before installing and commissioning product this chapter must thoroughly read and understood.

▲ DANGER

Indicates an imminently hazardous situation which will result in death or serious injury if you don't follow instructions.

▲ WARNING

Indicates a potentially hazardous situation which could result in death or serious injury if you don't follow instructions.

▲ CAUTION

Indicates a potentially hazardous situation which if not avoided, may result in minor injury or moderate injury if you don't follow instructions.

▲ DANGER

Current transformer (CT) circuit

Newer allow the current transformer (CT) secondary circuit to be opened, while the primary system is alive. Open CT secondary circuit will cause dangerously high voltage. Current transformer secondary circuit must be short circuited!

▲ WARNING

Voltage transformer (VT) circuit

Newer allow the voltage transformer (VT) secondary circuit to be short circuited, while the primary system is alive. Voltage transformer secondary circuit must be open!

▲CAUTION**Fibre optic**

Where fibre optic devices are fitted, these should not be viewed directly. Optical beam when connected could injury the eyes.

Exposed terminals

Do not touch the terminals of this equipment while the power is on, as the high voltage generated is dangerous.

Residual voltage

Hazardous voltage can be present in the DC circuit just after switching off the DC power supply. It is wise to wait 30 seconds for the voltage to discharge.

1.2. Testing equipment

This chapter describes the equipment which is needed to test relay system in a reliable way. The following article shows which equipment is necessary and which equipment is highly recommended.

Necessary equipment:

- Secondary testing device (single phase or three phase device)
- Digital multimeter (at least one)
- PC (used in relay setting)
- Calculator
- Timer (only when testing device don't have time measurement option)
- Bright flashlight (only when ARC-option is used)

Highly recommended equipment:

- Secondary testing device with adjustable phase angle
- Analog multimeter (used in testing of CT and VT polarity)
- Normal 5 volt battery (used in testing of CT and VT polarity)
- Normal switch (used in testing of CT and VT polarity)

It is highly recommended that secondary testing device have a possibility to change phase angle. This is necessary in testing of directional earth fault (67N) and directional overcurrent (67). Relay protection stages testing must be always done in AC-current and voltage.

Secondary testing devices and meters must be accurate to provide reliable results in commissioning tests.

2. Pre-inspection procedures

This chapter describes procedures, which are recommended before starting the protection relay commissioning tests. Following procedures must be done to make sure that relay is mounted and commissioned correctly.

First procedure before starting commissioning tests is to write the basic information of relay in to the commissioning report. Commissioning report is in appendix 1. Fill up following data:

- Customer name and information of substation and bay
- Relay type and serial number
- Relay software-version and hardware version
- Information of current transformers and voltage transformer

Visual inspection

1. Check the device visually for possible external damage or loose parts inside the device. Check also that device is clean and that device has no marks of damage etc.
2. Check that device applies in to expectation. Device model is correct and matches to ordered. Check that serial number of relay is correct and rated values are correct. Rated values can be found from the serial number sticker.
3. Check that the auxiliary voltage of relay is correct. Auxiliary voltage values can be found from serial number sticker and also in the 200-series rear panel just above the earthing terminal.
4. Check that the rated values of the VT and CT secondaries comply with those in relay. Check also that the load ability of the outputs is adequate.
5. Check that the relay is earthed by connecting an earthing wire to the relays earthing terminal. Minimum cross section of earthing wire is 2,5 mm². Check that the cable shields of shielded signal cables are connected to the earth terminal of relay.

When all 5 sections of visual inspection is checked and found out O.K. Write the note OK to commissioning report site visual inspection.

Checking of the wiring

1. Check that the relay is wired to rest of the process correctly according to the wiring diagrams of the application. This checking must be done very accurate to eliminate possible incorrect wirings, which cause malfunction of the relay and associated devices!
2. Check all the connections (relay connectors X1, X2, X3, X7, and X6 if Arc-option is used) between the relay and associated devices by using a circuit indicator lamp or digital multimeter buzzer.
3. Check other possible connections by using recognized and reliable working practices. Check all the screw terminals for correct tightness.
4. Check that the electrical connection wires comply with following requirements of maximum dimension:
 - **Measuring circuit:** Maximum wire dimension 4 mm², solid or stranded wire (10-12 AWG)
 - **Aux. voltage, digital inputs, trip contacts, alarm contacts and IF:** Maximum wire dimension 2,5 mm², Phoenix MVSTBW or equivalent (13-14 AWG)

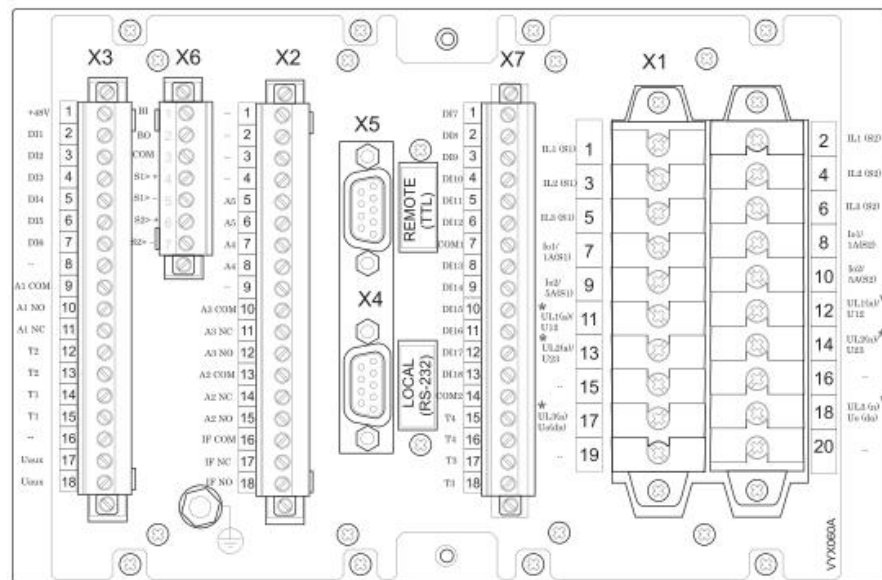


Figure 2-1 The rear panel connections of Vamp 255 (including Arc-protection option connector X6)

When all 4 sections of wiring is checked and found out O.K. Wite the note OK to commissioning report site wiring inspection.

CT and VT inspection

⚠ DANGER

Current transformer secondary circuit must be short circuited!

⚠ CAUTION

Voltage transformer secondary circuit must be open!

Current transformer and voltage transformer inspection is very important procedure in relay commissioning. Most of the relay measurement problems can be avoided by proper CT and VT inspection.

In CT and VT inspection must be checked at least transformers polarity, earthing, load, star point and preceding safety issues.

CT primaries P1 must be always connected towards bus-bar. Secondary star point must be correctly mounted considering bus-bar in all three-phased CT's which is generated to three one-phased CT's.

CT polarity can be tested by using following connection. Analog multimeter needle sweeps in positive direction when battery is connected and in negative direction when battery is disconnected by using switch K.

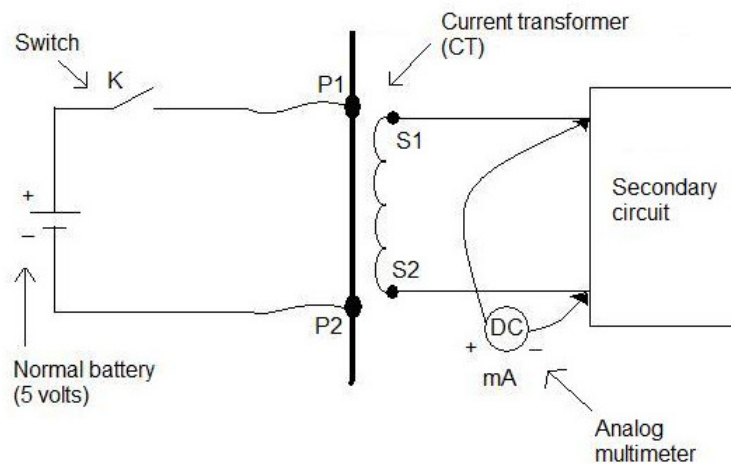


Figure 2-2 Procedure for checking CT polarity.

VT polarity can be tested by same methods. Figure 2-3 shows the connection for VT polarity testing. Analog multimeter needle sweeps in positive direction when battery in connected and in negative direction when battery is disconnected by using switch K.

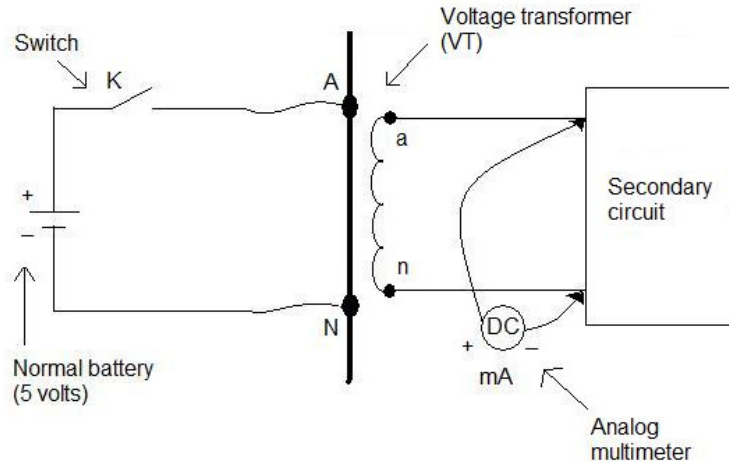


Figure 2-3 Procudere for checking VT polarity

In instrument transformer inspection is important to supply current to primaries of transformers to see secondary circuit consistency, correctness of transformation ratio, and possible loose contacts.

This same procedure is practical to inspection of multi-core transformers to see that measuring core and protection core is connected correctly.

Procedures:

1. Check the CT and VT polarity, earthing, load and star point connections.
2. Check the instrument and multi-core transformers secondary circuit consistency, correctness of transformation ratio, and possible loose contacts.

When these 2 procedures are done in reliable way and found out O.K. write the note OK to commissioning report site CT and VT inspection.

3. Adapting to local frequency and scaling

The VAMP 255 needs to know the local line frequency to be able to use synchronized sampling, where numerical technique is primarily based. The frequency is determined from signal connected to current input IL1.

Adapting the local frequency is done by connecting a current 0,5-1 A of local line frequency into IL1 input of the relay for a time of one minute.

Next it is sensible to set correct scaling values to relay. This setting can be done by using VAMPSET-relay setting tool. Scaling values depend on what kind of current and voltage transformers are used. It is important to set correct scaling values because those affect on used testing values in almost every protection stages.

FEEDER MANAGER VAMP 255
Protected target
Bay
Substation

SCALING

| | |
|---------------|-------|
| CT primary | 500 A |
| CT secondary | 5 A |
| Nominal input | 5 A |

| | |
|--------------|---------|
| VT primary | 11000 V |
| VT secondary | 100 V |

| | |
|-------------------|-------|
| Io1 CT primary | 50 A |
| Io1 CT secondary | 5.0 A |
| Nominal Io1 input | 1.0 A |
| Io2 CT primary | 50 A |
| Io2 CT secondary | 5.0 A |
| Nominal Io2 input | 5.0 A |

| | |
|--------------------|-----------|
| Vto secondary | 100.000 V |
| Voltage meas. mode | 2LL+Uo |

Figure 3-1 Scaling values setting with VAMPSET

Basic connections for testing device

Secondary testing device connections depend on what kind of secondary testing device is used. Also a different protection functions have a different kind of connections. It is wise to connect the testing device always to the connection strip.

Figure 3-2 shows the basic connection for three-phase secondary testing device.

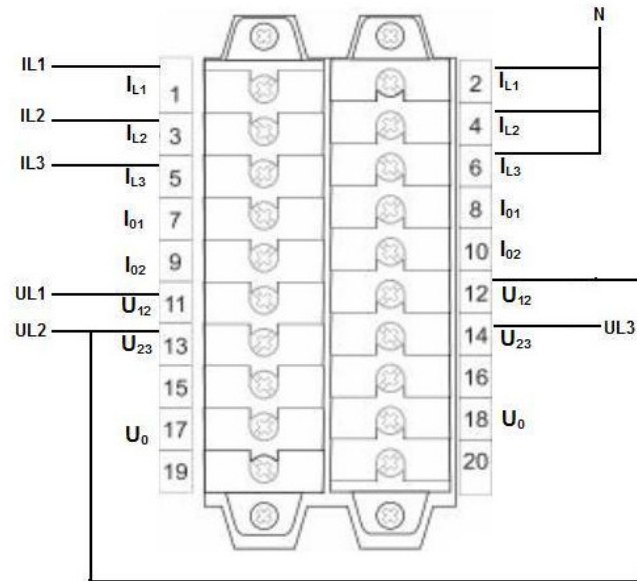


Figure 3-2 Three-phase basic connection for secondary testing device

Figure 3-3 shows the basic connection for single-phase secondary testing device.

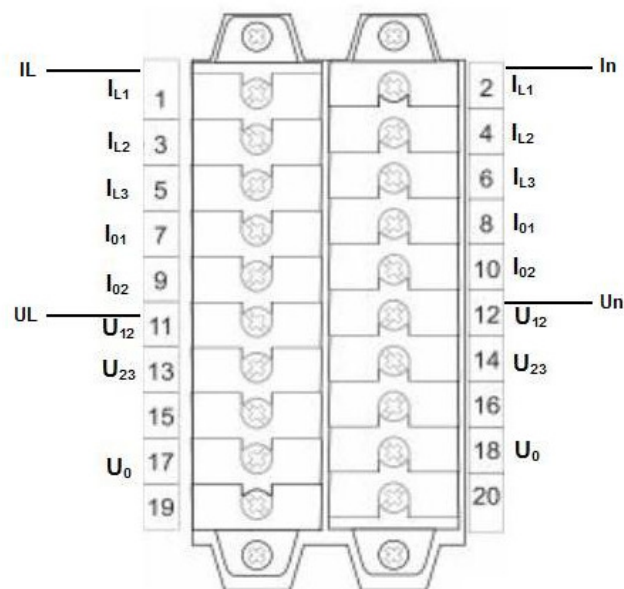


Figure 3-3 Single-phase basic connection for secondary testing device

Operation time is measured from used output relay. Normally used output relay is T1, which is in connector X3 inputs 14 and 15. Timer must be connected that it starts when fault current or voltage is injected and stops when relay trips.

Testing of protection stages is practical to do stage at a time. Selecting of the active stages is done in menu “valid protection stages (see Figure 3-4).

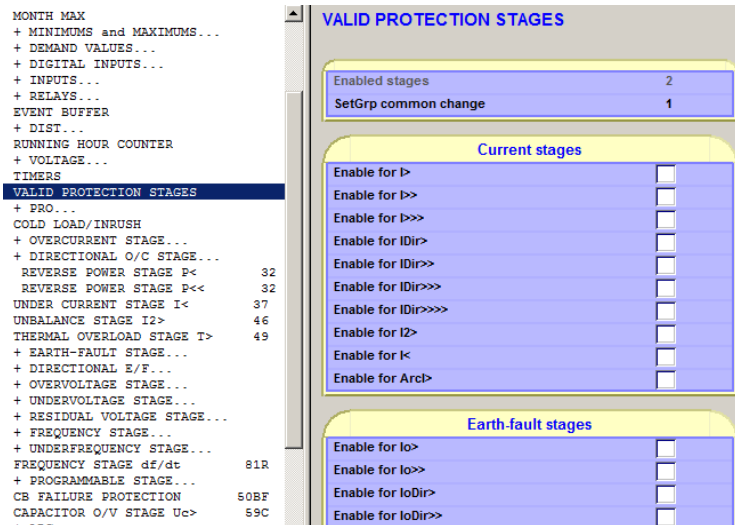


Figure 3-4 Selection of valid protection stages

4. Overcurrent protection stages testing

This chapter describes methods of testing Vamp 255 overcurrent protection stages. There are also some pre-calculated values which can be used in testing.

4.1. Overcurrent stage I> (50/51)

Overcurrent settings are usually given by designer of network. Network designers information include trip levels of each stages (I>, I>>, etc.) and also an operation time if definite time function is used.

If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

Setting values for relay testing must be marked in commissioning report site, setting values for overcurrent I>. Results of the test must be marked in commissioning report site, results for overcurrent I> test.

4.1.1. Trip level test

When single phased testing device is used, this test must be done in each phases. Connect the testing device to relays current inputs IL1, IL2, and IL3.

⚠WARNING

Remember to close the current supply on testing device while changing the connection to avoid electrical shock.

Example values for trip level test:

- relay nominal current $I_N = 1$ A (same as CT secondary current)
- stage I>: pick up level $1x I_N$

Increase the current and write down pick up current for stage I> to the commissioning report.

The actual pick up current should be within $\pm 3\%$ on setting values.

When example values is used, pick up current should be within 0,97 .. 1,03 A on stage I>.

This test must be done on each phase (when single phase testing device is used) and results are marked in commissioning report.

4.1.2. Operation time test (definite time)

Use network designer values in this testing if possible. If these values are not available, use following example values or our own example values. Remember to write down setting values on commissioning report.

Example values for definite operation time test:

- Definite operation time for stage I>: 0,3 s

Test stage I> by supplying 1,5 .. 2 x I_N current to each current inputs and measuring the operation time on output relay by using a timer.

The operation time including the inertia of the output relay should be within ±0,03 seconds on setting values.

When example values is used operation time should be on stage I> between 0,270 .. 0,330 seconds.

This test must be done on each phase (when single phase testing device is used) and results are marked in commissioning report.

4.1.3. Operation time test (inverse time)

When inverse time function is used, first thing to do is calculate used inverse time, and mark it to the commissioning report site: setting values, trip time I>.

There are four types of IEC inverse delay time characteristics:

- NI = NORMAL INVERSE
- VI = VERY INVERSE
- EI = EXTREMELY INVERSE
- LTI = LONG TIME INVERSE

Equations for each type are:

Equation 4.1.3-1 NI

$$t_{NI} = \frac{0,14k}{\left(\frac{I_{INJ}}{I_{SetSec}}\right)^{0,02} - 1}$$

Equation 4.1.3-2 VI

$$t_{VI} = \frac{13,5k}{\frac{I_{INJ}}{I_{SetSec}} - 1}$$

Equation 4.1.3-3 EI

$$t_{EI} = \frac{80k}{\left(\frac{I_{INJ}}{I_{SetSec}}\right)^2 - 1}$$

Equation 4.1.3-4 LTI

$$t_{LTI} = \frac{120k}{\frac{I_{INJ}}{I_{SetSec}} - 1}$$

where

I_{INJ} = injected current to the relay

I_{SetSec} = setting value scaled to CT secondary side

k = inverse time multiplier (see chapter 2.3.1 in VAMP 255 technical description)

With following example values inverse operation time can be tested. First example is for normal inverse NI, second example is for very inverse VI, third example is for extremely inverse EI and finally fourth example is for long time inverse LTI.

Example 1 (values for NI):

I_{INJ} = 1,5 A

I_{SetSec} = 1,0 A

k = 0,5

Operation time t_{NI} according to Equation 4.1.3-1 will be

$$t_{NI} = \frac{0,14 * 0,5}{\left(\frac{1,5}{1,0}\right)^{0,02} - 1} = 8,60 \text{ s}$$

The operation time including the inertia of the output relay should be within $\pm 5\%$: 8,17 .. 9,03 s.

Example 2 (values for VI):

I_{INJ} = 3,0 A (twice the current of example 1)

I_{SetSec} = 1,0 A

k = 0,1

Operation time t_{VI} according to Equation 4.1.3-2 will be

$$t_{VI} = \frac{13,5 * 0,1}{\frac{3,0}{1,0} - 1} = 675 \text{ ms}$$

The operation time including the inertia of the output relay should be within $\pm 5\%$: 641 .. 709 ms.

Example 3 (values for EI):

$$\begin{aligned} I_{INJ} &= 1,5 \text{ A} \\ I_{SetSec} &= 1,0 \text{ A} \\ k &= 0,5 \end{aligned}$$

Operation time t_{EI} according to Equation 4.1.3-3 will be

$$t_{EI} = \frac{80 * 0,5}{\left(\frac{1,5}{1,0}\right)^2 - 1} = 32,0 \text{ s}$$

The operation time including the inertia of the output relay should be within $\pm 5\%$: 30,4 .. 33,6 s.

Example 4.(values for LTI):

$$\begin{aligned} I_{INJ} &= 3,0 \text{ A (twice the current of example 1)} \\ I_{SetSec} &= 1,0 \text{ A} \\ k &= 0,1 \end{aligned}$$

Operation time t_{VI} according to Equation 4.1.3-4 will be

$$t_{LTI} = \frac{120 * 0,5}{\frac{3,0}{1,0} - 1} = 30,0 \text{ s}$$

The operation time including the inertia of the output relay should be within $\pm 5\%$: 28,5 .. 31,5 s.

This test must be done on each phase (when single phase testing device is used) and results are marked in commissioning report. Compare the result for the calculated value and check that it is inside the margin.

There are also four different kind of inverse delay characteristics, IEEE, IEEE2, RI and RXIDG. Equations for these inverse delay characteristics are following.

IEEE:

$$t = k \left[\frac{A}{\left(\frac{I}{I_{pickup}} \right)^C - 1} + B \right], \text{ where}$$

t = operation delay in seconds

k = User's multiplier

I = Measured value

I_{pickup} = User's pick up setting

A,B,C = Constant parameter according Table 4.1.3-1

Table 4.1.3-1 Constants for IEEE

| Delay type | | Parameter | | |
|------------|------------------------------|-----------|---------|------|
| | | A | B | C |
| LTI | Long time inverse | 0.086 | 0.185 | 0.02 |
| LTVI | Long time very inverse | 28.55 | 0.712 | 2 |
| LTEI | Long time extremely inverse | 64.07 | 0.250 | 2 |
| MI | Moderately inverse | 0.0515 | 0.1140 | 0.02 |
| VI | Very inverse | 19.61 | 0.491 | 2 |
| EI | Extremely inverse | 28.2 | 0.1217 | 2 |
| STI | Short time inverse | 0.16758 | 0.11858 | 0.02 |
| STEI | Short time extremely inverse | 1.281 | 0.005 | 2 |

IEEE2:

$$t = k \left[A + \frac{B}{\left(\frac{I}{I_{pickup}} \right)^C - C} + \frac{D}{\left(\frac{I}{I_{pickup}} \right)^2 - C} + \frac{E}{\left(\frac{I}{I_{pickup}} \right)^3 - C} \right], \text{ where}$$

t = operation delay in seconds

k = User's multiplier

I = Measured value

I_{pickup} = User's pick up setting

A,B,C,D,E = Constant parameter according Table 1

Table 4.1.3-2 Constants for IEEE2

| Delay type | | Parameter | | | | |
|------------|--------------------|-----------|--------|------|--------|--------|
| | | A | B | C | D | E |
| MI | Moderately inverse | 0.1735 | 0.6791 | 0.8 | -0.08 | 0.1271 |
| NI | Normally inverse | 0.0274 | 2.2614 | 0.3 | -.1899 | 9.1272 |
| VI | Very inverse | 0.0615 | 0.7989 | 0.34 | -0.284 | 4.0505 |
| EI | Extremely inverse | 0.0399 | 0.2294 | 0.5 | 3.0094 | 0.7222 |

RI and RXIDG:

$$t_{RI} = \frac{k}{0.339 - \frac{0.236}{\left(\frac{I}{I_{pickup}}\right)}}$$

$$t_{RXIDG} = 5.8 - 1.35 \ln \frac{I}{kI_{pickup}}, \text{ where}$$

- t = operation delay in seconds
k = User's multiplier
I = Measured value
I_{pickup} = User's pick up setting

For more inverse delay characteristics information, see Chapter Inverse time operation of VAMP 255 manual.

4.2. Directional overcurrent stage I_{dir}> (67)

Testing of directional overcurrent needs a secondary testing device where phase angle can be adjusted.

The stages are sensitive to the amplitude of the highest fundamental frequency current of the measured three phase currents. The phase angle is based on the phase angle of the three-phase power phasor. A typical characteristic is shown in Figure 4.2-1. The base angle setting is -30°. The stage will pick up, if the tip of the three phase current phasor gets into the grey area.

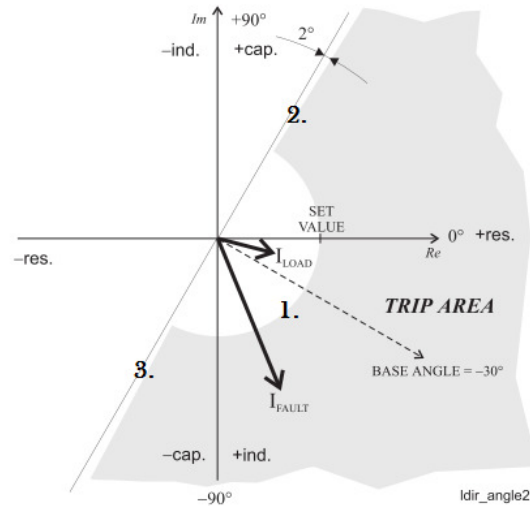


Figure 4.2-1 Typical characteristic for directional overcurrent

There are three points in the characteristic where stage functionality must be tested. Points are marked in the Figure 4.2-1 with numbers 1, 2, and 3. First point is normal overcurrent test with the phase angle 0° . Second point and third point testing is done by changing the phase angle while overcurrent and nominal voltage is supplied.

4.2.1. Trip level test

Example values for trip level test in point 1:

| | | |
|--------------|---|---|
| U_{VTSEC} | = | 100 V |
| I_{CTSEC} | = | 1 A |
| I_{SET} | = | $1,2 \times I_{CTSEC}$ |
| t | = | 0,1 s (Set the definite operation time to it's minimum to make the test easier) |
| Angle offset | = | -30° |
| U_{INJ} | = | 100 V |
| Phase angle | = | 0° |

The secondary pick up current will be

$$I_{INJ} = I_{CTSEC} \times I_{SET} = 1 \text{ A} \times 1,2 = 1,2 \text{ A}$$

The actual pick up current should be within $\pm 3\% = 1,16 \dots 1,24$ A. To find out actual pick up level start with current 1,1 A. Then increase current in small steps until the relay picks up. Mark the pick up value in commissioning report.

Example values for trip level test in point 2:

$$U_{VTSEC} = 100 \text{ V}$$

$$I_{CTSEC} = 1 \text{ A}$$

$$I_{SET} = 1,2 \times I_{CTSEC}$$

$$t = 0,1 \text{ s} \quad (\text{Set the definite operation time to it's minimum to make the test easier})$$

$$\text{Angle offset} = -30^\circ$$

$$U_{INJ} = 100 \text{ V}$$

$$I_{INJ} = 1,5 \text{ A}$$

Let's calculate the phase angle where relay should trip in point 2.

$$\text{Trip angle} = 180^\circ - 90^\circ - \text{angle offset} - 2^\circ$$

$$\text{Trip angle} = 180^\circ - 90^\circ - 30^\circ - 2^\circ = 58^\circ$$

The actual pick up phase angle should be within $\pm 2^\circ = 56^\circ \dots 60^\circ$. To find out actual pick up angle start with phase angle 64° . Then decrease the angle in small steps until the relay picks up. Mark the pick up value in commissioning report.

Let's calculate the phase angle where relay should trip in point 3.

$$\text{Trip angle} = 180^\circ + 90^\circ - \text{angle offset} + 2^\circ$$

$$\text{Trip angle} = 180^\circ + 90^\circ - 30^\circ + 2^\circ = 242^\circ$$

Other values same as in point 2.

The actual pick up phase angle should be within $\pm 2^\circ = 240^\circ \dots 244^\circ$. To find out actual pick up angle start with phase angle 236° . Then increase the angle in small steps until the relay picks up. Mark the pick up value in commissioning report.

Preceding values work with three-phase test and single-phase test in situations when devices voltage measurement mode is 3LL. When voltage measurement mode is 2LL+U0 preceding values work only in single-phase test. When testing is done in three-phase, and used mode is 2LL+U0 we have to use following equations to calculate trip angle on points 2 and 3.

$$\text{Point 2 trip angle} = 180^\circ - 90^\circ - 30^\circ - \text{angle offset} - 2^\circ$$

$$\text{Point 3 trip angle} = 180^\circ + 90^\circ - 30^\circ - \text{angle offset} + 2^\circ$$

Notice also that voltages in mode 2LL+U₀ and single-phase testing must be connected as in single-phase undervoltage testing (see Figure 5.2.2-1).

4.2.2. Operation time test

The specified operation time accuracy is achieved when the current is $>200\%$ of the setting value.

Example values for operation time test:

$$t = 0,5 \text{ s}$$

$$I_{INJ} = 2,00 \times 1,2 \text{ A} = 2,4 \text{ A}$$

Other settings same as in preceding trip level test in point 1.

The operation time including the inertia of the output relay should be within $\pm 30 \text{ ms}$: $0,470 \dots 0,530 \text{ s}$.

Write down the results in commissioning report.

If inverse time operation is used, trip time must be calculated as in preceding non-directional overcurrent test. Mark calculated value in commissioning report and compare it to measured value. Measured value should be within $\pm 5\%$.

5. Earth fault protection stages testing

This chapter describes methods of testing VAMP 255 earth fault protection stages. There are also some pre-calculated values which can be used in testing.

5.1. Earth fault stage $I_{0>}$ (50N/51N)

VAMP 255 has two separate energizing rated 1 A ($I_{0>}$ and $I_{0>>}$) and 5 A ($I_{0>>>}$ and $I_{0>>>>}$), both can be used simultaneously. The function of stages $I_{0>}$ and $I_{0>>}$ is based on the measured current connected to the input 4 (terminal X1:7-8). The function of stages $I_{0>>>}$ and $I_{0>>>>}$ is based on the measured current connected to the input 5 (terminal X1:9-10).

This stage is measuring primary earth fault current I_0 . Setting value of this stage is a per unit (p.u.) value of the residual CT nominal value.

If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

5.1.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for earth fault stage $I_{0>}$. Results of the test must be marked in commissioning report site, results for earth fault stage $I_{0>}$ test.

Example values for trip level test:

$$\begin{aligned} I_{CTtoSEC} &= 5 \text{ A} \\ I_{0SET} &= 0,05 \text{ p.u.} \end{aligned}$$

The secondary pick up current will be

$$I_{INJ} = I_{CTtoSEC} \times I_{0SET} = 5 \text{ A} \times 0,05 = 0,25 \text{ A}$$

The actual pick up current should be within $\pm 5\% = 0,237 \dots 0,263 \text{ A}$. To find out actual pick up level, start with current 0,220 A. Then increase current in small steps until the relay picks up. Mark the pick up value in commissioning report.

5.1.2. Operation time test

Use network designer values in this testing if possible. If these values are not available, use following example values or our own example values. Remember to write down setting values on commissioning report.

The specified operation time accuracy is achieved when the current is >200% of the setting value.

Example values for operation time test:

$$t = 0,5 \text{ s}$$

$$I_{INJ} = 2,05 \times 0,25 \text{ A} = 0,513 \text{ A}$$

Other settings same as in preceding trip level test

The operation time including the inertia of the output relay should be within $\pm 30 \text{ ms}$: 0,470 .. 0,530 s.

Write down the results in commissioning report.

5.2. Directional earth fault stage $I_{0\phi} > (67N)$

Testing of directional earth fault needs a secondary testing device where phase angle can be adjusted.

VAMP 255 includes two residual current inputs. This stage is using input I_{01} or I_{02} depending which is selected. Directional residual current function is using residual voltage to solve the direction. Residual voltage input is U_0 .

There are three modes in this stage: sector, resistive and capacitive. The resistive mode is for resistance-earthed networks and the capacitive mode is for isolated networks. The mode can be pre-selected or it can be dynamically controlled by any digital input. In sector mode trip area size can be manually selected. There are pre-calculated values for each of these three modes.

The residual current setting is a per unit (p.u.) value of the residual current transformer nominal value.

Figure 5.2-1 shows example characteristic for directional earth fault. Grey area is trip area. Functionality must be tested in points 1, 2 and 3.

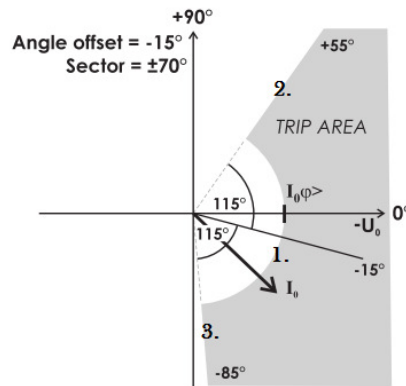


Figure 5.2-1 Example characteristic for directional earth fault (sector mode)

5.2.1. Trip level test in sector mode

Trip level test must be done in points 1, 2, and 3. First point is normal earth fault current test with the phase angle 0° . Second point and third point testing is done by changing the phase angle while earth fault current and residual voltage is supplied.

Setting values for relay testing must be marked in commissioning report site, setting values for directional earth fault $I_{0\phi>}$. Results of the test must be marked in commissioning report site, results for directional earth fault $I_{0\phi>}$ test.

Example values for trip level test in point 1:

| | | |
|----------------|---|---|
| U_{VT0SEC} | = | 100 V |
| I_{CT0SEC} | = | 1 A |
| I_{0SET} | = | 0,2 p.u. |
| T | = | 0,1 s (Set the definite operation time to it's minimum to make the test easier) |
| Direction mode | = | Sector |
| U_{0MIN} | = | 10% (Minimum residual voltage for stage to operate) |
| sector size | = | $\pm 70^\circ = 140^\circ$ |
| angle offset | = | -15° |
| phase angle | = | 0° |

The secondary pick up current will be

$$I_{INJ} = I_{CT0SEC} \times I_{0SET} = 1 \text{ A} \times 0,2 = 0,2 \text{ A}$$

Minimum residual voltage for the stage to operate is

$$U_{0MinInj} = U_{VT0SEC} \times U_{0min} = 100 \text{ V} \times 0,1 = 10 \text{ V}$$

The injected voltage should be more, e.g. 10%, than the minimum to ensure precise operation of the stage.

$$U_{\text{INJ}} = 1,1 \times 10 \text{ V} = 11 \text{ V}$$

The phase angles of the injected current and voltage must be equal.

The actual pick up current should be within $\pm 3\% = 0,194 \dots 0,206 \text{ A}$. To find out actual pick up level start with current $0,180 \text{ A}$. Then increase current in small steps until the relay picks up. Mark the pick up value in commissioning report.

Example values for trip level test in point 2:

$$U_{\text{INJ}} = 11 \text{ V}$$

$$I_{\text{INJ}} = 2 \times \text{pick up current} = 2 \times 0,2 \text{ A} = 0,4 \text{ A}$$

$$\text{sector size} = \pm 70^\circ = 140^\circ$$

$$\text{angle offset} = -15^\circ$$

Other values same as in preceding trip level test

Let's calculate the phase angle where relay should trip in point 2.

$$\text{Trip angle} = \text{sector size} - \text{half of the sector} - \text{angle offset}$$

$$\text{Trip angle} = 140^\circ - 70^\circ - 15^\circ = 55^\circ$$

The actual pick up phase angle should be within $\pm 2^\circ = 53^\circ \dots 57^\circ$. To find out actual pick up angle start with phase angle 60° . Then decrease the angle in small steps until the relay picks up. Mark the pick up value in commissioning report.

Let's calculate the phase angle where relay should trip in point 3.

$$\text{Trip angle} = 360^\circ - \text{half of the sector} - \text{angle offset}$$

$$\text{Trip angle} = 360^\circ - 70^\circ - 15^\circ = 275^\circ$$

Other values same as in point 2.

The actual pick up phase angle should be within $\pm 2^\circ = 273^\circ \dots 277^\circ$. To find out actual pick up angle start with phase angle 270° . Then increase the angle in small steps until the relay picks up. Mark the pick up value in commissioning report.

5.2.2. Trip level test in resistive and capacitive mode

Difference between resistive and capacitive mode is showed in Figure 5.2.2-1. In capacitive mode the trip area is leading 90 degrees.

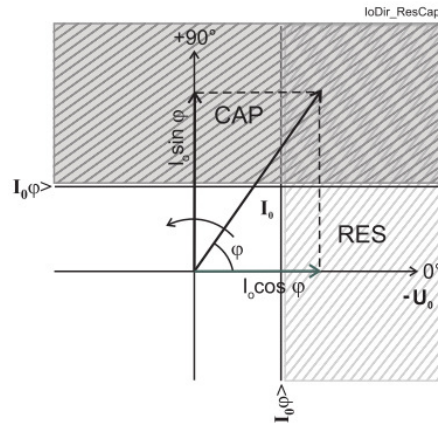


Figure 5.2.2-1 Difference between resistive and capacitive mode

Normal testing where current value is increased can be done as in preceding sector mode test. Sector size is in resistive and capacitive mode 180 degrees. In phase angle testing values must be calculated by different methods. In **resistive mode** phase angle values in trip point 1 and 2 is calculated by following method.

$$\begin{aligned}\text{Trip angle 1} &= \text{sector size} \cdot 90^\circ + \text{angle offset} \cdot 2^\circ \\ \text{Trip angle 2} &= \text{sector size} + 90^\circ + \text{angle offset} + 2^\circ\end{aligned}$$

Example trip angle values when angle offset is -45° .

$$\begin{aligned}\text{Trip angle 1} &= 180^\circ \cdot 90^\circ + (-45^\circ) \cdot 2^\circ = 45^\circ \pm 2^\circ \\ \text{Trip angle 2} &= 180^\circ + 90^\circ + (-45^\circ) + 2^\circ = 227^\circ \pm 2^\circ\end{aligned}$$

In **capacitive mode** phase angle values in trip point 1 and 2 is calculated by following method.

$$\begin{aligned}\text{Trip angle 1} &= 90^\circ + \text{sector size} \cdot 90^\circ + \text{angle offset} \cdot 2^\circ \\ \text{Trip angle 2} &= 90^\circ + \text{sector size} + 90^\circ + \text{angle offset} + 2^\circ\end{aligned}$$

Example trip angle values when angle offset is -45° .

$$\begin{aligned}\text{Trip angle 1} &= 90^\circ + 180^\circ \cdot 90^\circ + (-45^\circ) \cdot 2^\circ = 135^\circ \pm 2^\circ \\ \text{Trip angle 2} &= 90^\circ + 180^\circ + 90^\circ + (-45^\circ) + 2^\circ = 317^\circ \pm 2^\circ\end{aligned}$$

5.2.3. Operation time test

Use network designer values in this testing if possible. If these values are not available, use following example values or our own example values. Remember to write down setting values on commissioning report.

The specified operation time accuracy is achieved when the current is >200% of the setting value.

Example values for operation time test:

$t = 0,5 \text{ s}$
 $U_{INJ} = 11 \text{ V}$
 $I_{INJ} = 2,03 \times 0,2 \text{ A} = 0,406 \text{ A}$
phase angle = 0°

Other settings same as in preceding trip level test

The operation time including the inertia of the output relay should be within $\pm 30 \text{ ms}$: $0,470 \dots 0,530 \text{ s}$.

Write down the results in commissioning report.

6. Voltage protection stages testing

This chapter describes methods of testing VAMP 255 voltage protection stages. There are also some pre-calculated values which can be used in testing.

6.1. Residual voltage protection $U_0 >$ (59N)

The residual voltage function measures the fundamental frequency component of the residual voltage. This means that harmonics will not cause a trip. The protection stages operate with definite time characteristics.

The function starts if the actual value for the residual voltage exceeds the setting value. If the overvoltage situation continues after the start delay has elapsed, the function trips. In testing of residual voltage stage secondary injection is injected to input U_0 .

If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

6.1.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for residual voltage stage $U_0 >$. Results of the test must be marked in commissioning report site, results for residual voltage stage $U_0 >$ test.

Example values for trip level test:

$$U_{VT0SEC} = 100 \text{ V}$$

$$U_{SET} = 10 \%$$

$$t = 0,3 \text{ s (set definite operation time to its minimum to make the test easier)}$$

Injected secondary residual voltage that should start the protection stage

$$U_{INJ} = U_{VT0SEC} \times U_{SET} = 100 \text{ V} \times 0,10 = 10,0 \text{ V}$$

The actual pick up voltage should be within $\pm 2\% = 9,8 \dots 10,2 \text{ V}$. To find out the actual pick up level start with the voltage $9,0 \text{ V}$. The increase the injection in small steps until the relay picks up.

Mark the setting values and pick up values in the commissioning report.

6.1.2. Operation delay test

The specified operation time accuracy is achieved when the fault voltage is $>200\%$ of the setting value.

Example values for operation delay test:

$$U_{VT0SEC} = 100 \text{ V}$$

$$U_{SET} = 10 \%$$

$$t = 2 \text{ s}$$

$$U_{INJ} = 2,02 \times 10 \text{ V} = 20,2 \text{ V} \text{ (200\% + tolerance 2\% yields to multiplier 2,02)}$$

The operation time including the inertia of the output relay should be within $\pm 150 \text{ ms}$: $1,85 \dots 2,15 \text{ s}$.

Mark the setting value of operation time and measured operation time to the commissioning report.

6.2. Overvoltage protection $U >$ (59)

The three phase overvoltage function consists of three separately adjustable overvoltage stages $U >$, $U >>$, and $U >>>$. The overvoltage function measures the fundamental frequency component of the line voltages. The protection stages operate with definite time characteristics.

The function picks up if the actual value of any phase exceeds the setting value. If an overvoltage situation continues after the operation time has elapsed, the function trips. In testing of overvoltage stage secondary injection is injected to inputs U_{12} or U_{23} or both inputs.

If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

While voltage measurement mode is 3LL, this test must be done phase at a time, while single phase testing device is used.

6.2.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for overvoltage stage U>. Results of the test must be marked in commissioning report site, results for overvoltage stage U> test.

Example values for trip level test:

$$U_{VTPRI} = 11000 \text{ V}$$

$$U_{SET} = 120 \% \times U_{VTPRI}$$

$$U_{VTSEC} = 100 \text{ V}$$

$$t = 0,1 \text{ s (Set definite operation time to its minimum to make the test easier)}$$

The primary voltage that should start the protection stage is

$$U_{PRISET} = 1,2 \times 11000 \text{ V} = 13200 \text{ V}$$

The primary voltage that should start the protection stage is

$$U_{SECSET} = (100 \text{ V} / 11000 \text{ V}) \times 13200 \text{ V} = 120 \text{ V}$$

Injected secondary voltage that should start the protection stage is same as U_{SECSET} .

$$U_{INJ} = 120 \text{ V}$$

The actual pick up voltage should be within $\pm 3\% = 116,4 \dots 123,6 \text{ V}$. To find out the actual pick up level start with the voltage 110 V. Then increase the injection in small steps until the relay picks up.

Mark the setting values and pick up values in the commissioning report.

6.2.2. Operation time test

The specified operation time accuracy is achieved when the voltage before the fault is $>90\%$ of the setting value and the fault voltage is 110% of the setting value.

Example values for operation delay test:

$$U_{VTSEC} = 100 \text{ V}$$

$$U_{SET} = 120 \%$$

$$t = 0,5 \text{ s}$$

Voltage before the fault is

$$U_{\text{INJpre}} = 0,9 \times 120 \text{ V} = 108 \text{ V}$$

Fault voltage is

$$U_{\text{INJ}} = 1,12 \times 120 \text{ V} = 135 \text{ V}$$

Increase the secondary injection in fast step from 108 V to 135 V.

The operation time including the inertia of the output relay should be within ± 30 ms: 0,47 .. 0,53 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

6.3.

Undervoltage protection U< (27)

The three-phase undervoltage function consists of three separately adjustable undervoltage stages (stage U<, U<<, and U<<<). The protection stages operate with definite time characteristics.

The undervoltage function measures the positive sequence component of the line voltages. The function starts if a positive sequence component exceeds the setting value. If the undervoltage situation continues after the start delay has elapsed, the function trips.

In testing of undervoltage stage secondary injection is injected to inputs U_{12} or U_{23} or both inputs. If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

Connect the line inputs to the relay parallel. Note that connecting the inputs in series is incorrect for this test. Figure 6.3-1 shows connection for single phase testing.

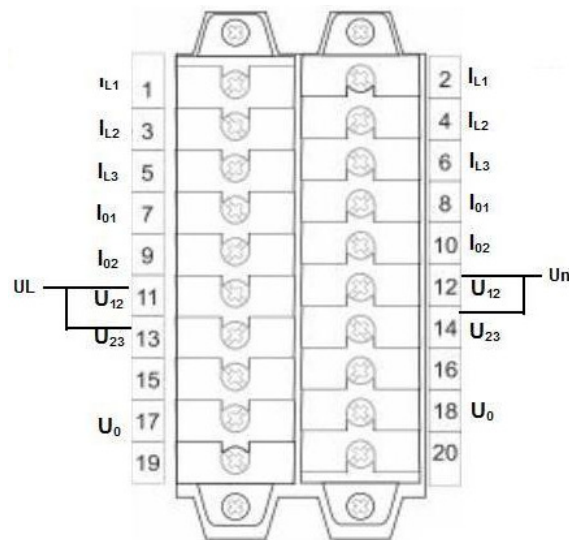


Figure 6.3-1 Connection for single phase undervoltage testing

6.3.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for undervoltage stage $U_{<}$. Results of the test must be marked in commissioning report site, results for undervoltage stage $U_{<}$ test.

Example values for trip level test:

$$U_{VTPRI} = 11000 \text{ V}$$

$$U_{SET} = 80 \% \times U_{VTPRI}$$

$$U_{VTSEC} = 100 \text{ V}$$

$$t = 0,1 \text{ s (Set definite operation time to its minimum to make the test easier)}$$

First inject about 5% more than the trip level.

$$U_{12} = U_{23} = 1,05 \times 0,8 \times 100 \text{ V} = 84 \text{ V}$$

Injected secondary voltage that should start the protection stage

$$U_{12} = U_{23} = 0,8 \times 100 \text{ V} = 80 \text{ V}$$

The actual pick up voltage should be within $\pm 3\% = 82,4 \dots 77,6 \text{ V}$. To find out the actual pick up level start with the voltage 84 V. Then decrease the injection in small steps until the relay picks up.

Mark the setting values and pick up values in the commissioning report.

6.3.2. Operation time test

The specified operation time accuracy is achieved when the voltage before the fault is >110% of the setting value and the fault voltage is 90 % of the setting value.

Example values for operation delay test:

$$U_{VTSEC} = 100 \text{ V}$$

$$U_{SET} = 80 \%$$

$$t = 0,5 \text{ s}$$

Voltage before the fault is

$$U_{INJpre} = 1,1 \times 80 \text{ V} = 88 \text{ V}$$

Fault voltage is

$$U_{INJ} = 0,87 \times 80 \text{ V} = 69,6 \text{ V} \text{ (90\% - tolerance 3\% yields to multiplier 0,87)}$$

Decrease the secondary injection in fast step from 88 V to 69,6 V.

The operation time including the inertia of the output relay should be within ± 30 ms: 0,47 .. 0,53 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

7. Frequency protection stages testing

This chapter describes methods of testing VAMP 255 frequency protection stages. There are also some pre-calculated values which can be used in testing.

It is required to have a device with adjustable frequency output in the frequency tests.

The overfrequency and underfrequency consist of two separately adjustable frequency stages (stage $f >$ or abbreviated form fX and $f <$ or abbreviated form fXX). The protection stages operate with definite time characteristics.

The stages can be separately configured as either overfrequency or underfrequency stages. The frequency function measures the frequency based on the measured voltage depending on the configurations of the relay. Used voltage inputs for injection are inputs U12 or U23 or both inputs.

Overfrequency stage testing methods are in Chapter 7.1 and underfrequency testing method are in Chapter 7.2.

A big frequency step is interpreted as a disturbance by the device. That is why trip level and operation time should be tested using a smooth frequency change or a tiny frequency step. **The maximum sudden frequency change should not exceed 2,5 Hz.**

7.1. Overfrequency protection $f >$ (81H)

When a stage is configured as an overfrequency stage, it starts if the actual value of the frequency exceeds the setting value. If the overfrequency situation continues after the start delay has elapsed, the function trips.

7.1.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for overfrequency stage $f >$. Results of the test must be marked in commissioning report site, results for overfrequency stage $f >$ test.

Example values for trip level test:

$$f_{\text{SET}} = 51,0 \text{ Hz}$$
$$t = 0,2 \text{ s}$$

Inject the voltage with frequency 50 Hz in to input U_{12} or U_{23} or both.

$$U_{\text{INJ}} = 100 \text{ V @ 50 Hz}$$

The actual pick up frequency should be within $\pm 0,02 \text{ Hz} = 50,98 \dots 51,02 \text{ Hz}$. To find out the actual pick up level start with the frequency 50 Hz. Then slowly increase the frequency until the stage starts.

Mark the setting values and pick up values in the commissioning report.

7.1.2.

Operation time test

Example values for operation time test:

$$f_{\text{SET}} = 51,0 \text{ Hz}$$
$$t = 1,0 \text{ s}$$

Inject the voltage with frequency 50,9 Hz in to input U_{12} or U_{23} or both.

$$U_{\text{INJ}} = 100 \text{ V @ 50,9 Hz}$$

Increase the frequency in fast step from 50,9 Hz to 51,2 Hz.

The operation time including the inertia of the output relay should be within $\pm 30 \text{ ms}$: 0,97 .. 1,03 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

7.2. Underfrequency protection $f < (81L)$

The underfrequency function starts if the actual value for the frequency goes below the setting value. If an underfrequency situation continues after the start delay has elapsed, the function will trip.

7.2.1. Trip level test

Setting values for relay testing must be marked in commissioning report site, setting values for underfrequency stage $f <$. Results of the test must be marked in commissioning report site, results for underfrequency stage $f <$ test.

Example values for trip level test:

$$\begin{aligned}f_{\text{SET}} &= 49,0 \text{ Hz} \\t &= 0,2 \text{ s}\end{aligned}$$

Inject the voltage with frequency 50 Hz in to input U_{12} or U_{23} or both.

$$U_{\text{INJ}} = 100 \text{ V @ } 50 \text{ Hz}$$

The actual pick up frequency should be within $\pm 0,02 \text{ Hz} = 49,02 \dots 48,98 \text{ Hz}$. To find out the actual pick up level start with the frequency 50 Hz. Then slowly decrease the frequency until the stage starts.

Mark the setting values and pick up values in the commissioning report.

7.2.2. Operation time test

Example values for operation time test:

$$\begin{aligned}f_{\text{SET}} &= 49,0 \text{ Hz} \\t &= 0,1 \text{ s}\end{aligned}$$

Inject the voltage with frequency 49,1 Hz in to input U_{12} or U_{23} or both.

$$U_{\text{INJ}} = 100 \text{ V @ } 49,1 \text{ Hz}$$

Decrease the frequency in fast step from 49,1 Hz to 48,8 Hz.

The operation time including the inertia of the output relay should be within $\pm 30 \text{ ms}$: 0,97 .. 1,03 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

8. Other protection stages

8.1. Auto-reclose function (79)

Functionality of auto-reclose function is defined by auto-reclosing matrix (see Figure 8.1-1). AR-matrix defines which signals (start and trip signals from protection stages or digital inputs) are forwarded to the auto-reclose function.

Dead times and discrimination times for each AR-shots are defined in AR-shot settings (see Figure 8.1-2). Start delay of auto-reclose function is defined in shot 1 settings.

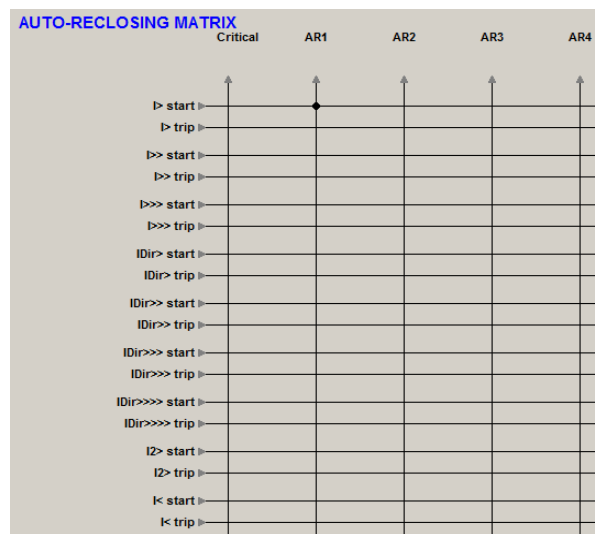


Figure 8.1-1. Auto-reclosing matrix

AR Shot settings 79

Use shot specific reclaim time

Reclaim time 10.00 s

Shot 1

| Enable | AR | Block | Start delay | Dead time | Discrimination time | Reclaim time |
|--------|----|-------|-------------|-----------|---------------------|--------------|
| On | 1 | - | 0.70 s | 0.30 s | 0.20 s | 10.00 s |
| Off | 2 | - | 0.02 s | 0.30 s | 0.02 s | 10.00 s |
| Off | 3 | - | 0.02 s | 0.30 s | 0.02 s | 10.00 s |
| Off | 4 | - | 0.02 s | 0.30 s | 0.02 s | 10.00 s |

Shot 2

| Enable | AR | Block | Dead time | Discrimination time | Reclaim time |
|--------|----|-------|-----------|---------------------|--------------|
| On | 1 | - | 10.00 s | 0.20 s | 10.00 s |
| Off | 2 | - | 10.00 s | 0.02 s | 10.00 s |
| Off | 3 | - | 10.00 s | 0.02 s | 10.00 s |
| Off | 4 | - | 10.00 s | 0.02 s | 10.00 s |

Shot 3

| Enable | AR | Block | Dead time | Discrimination time | Reclaim time |
|--------|----|-------|-----------|---------------------|--------------|
| On | 1 | - | 0.30 s | 0.20 s | 10.00 s |
| Off | 2 | - | 0.30 s | 0.02 s | 10.00 s |
| Off | 3 | - | 0.30 s | 0.02 s | 10.00 s |
| Off | 4 | - | 0.30 s | 0.02 s | 10.00 s |

Figure 8.1-2 AR-shot settings where dead times and discrimination times are defined

While testing the auto-reclose function it is wise to set start delay time shorter than actual trip time for used protection stage.

When testing auto-reclose function you must have timer which have a start and stop option and also a sequence option, where you can measure many times in a row. Measured times must stay in a timer memory, so that those can be examined after the whole auto-reclose sequence. Start signal for timer is got from breaker state signal. Stop signal for timer is got from trip relay which opens the breaker (see Figure 8.1-3).

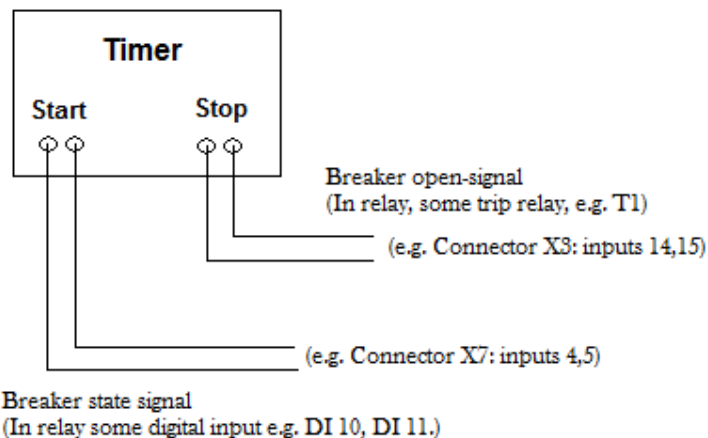


Figure 8.1-3 Timer connection for auto-reclose test

While testing auto-reclosing, use time values which networks protection designer specifies. If these values are not available, use following time values for dead time and discrimination time.

Example values for auto-reclosing test:

| | | |
|----------------------------|---|--|
| Used protection stage | = | Overcurrent stage I> |
| Start delay time | = | 0,5 s (must be shorter than actual trip time in selected protection stage) |
| Shot 1 dead time | = | 0,4 s |
| Shot 1 discrimination time | = | 0,2 s |
| Shot 2 dead time | = | 60 s |
| Shot 2 discrimination time | = | 0,2 s |
| Shot 3 dead time | = | 0,4 s |
| Shot 3 discrimination time | = | 0,2 s |
| Shot 4 dead time | = | 60 s |
| Shot 4 discrimination time | = | 0,2 s |

After this auto-reclosing sequence follows final trip.

Mark all the setting times in commissioning report site auto-reclosing.

When measuring actual times by using preceding timer connection, measured times also include breaker operation time. (This information is acquired from breaker manufacturer). This time must be noticed in measured times by reducing it from actual times. Measured times when breaker operation time is reduced must be within $\pm 5\%$ or ± 30 ms.

Maximum number of different signals which starts auto-reclose function is four. If protection system have more than one auto-reclosings, all of those must be tested with same principles as preceding. Commissioning report includes columns for all four possible auto-reclosings.

When all times are measured in a reliable way, mark down the results in commissioning report. If the times are inside the margin mark O.K.

8.2. Current unbalance protection (46)

Unbalance protection can be tested only with three-phase testing device!

The operation of the unbalance protection is based on the negative phase sequence component I_2 related to the positive phase sequence component I_1 . This is calculated from the phase currents using the method of symmetrical components. The function requires that the measuring inputs are connected correctly so that the rotation direction of the currents is correct.

Equation 8.2-1

$$K2 = \frac{I_2}{I_1}, \quad \text{where}$$

$$I_1 = I_{L1} + aI_{L2} + a^2I_{L3}$$

$$I_2 = I_{L1} + a^2 I_{L2} + aI_{L3}$$

$$a = 1\angle 120^\circ = -\frac{1}{2} + j\frac{\sqrt{3}}{2}, \text{ a phasor rotating constant}$$

8.2.1. Trip level test

Example values for trip level test:

$$\begin{aligned} I_{CTSEC} &= 5,00 \text{ A} \\ \text{pick up setting K2} &= 10\% \\ \text{operation time t} &= 1,0 \text{ s} \end{aligned}$$

Let's calculate which phase currents for example exceeds pick up setting.

$$\begin{aligned} I_{L1} &= 3,64 \angle 0^\circ \\ I_{L2} &= 5,00 \angle -120^\circ \\ I_{L3} &= 5,00 \angle 120^\circ \end{aligned}$$

When these phase currents is used, K2 according to Equation 8.2-1 is 10 %.

The actual pick up current I_{L1} should be within $\pm 0,05 \text{ A}$: 3,69 .. 3,59 A. To find out the actual pick up level start with the current 3,8 A. Then slowly decrease the current until the stage starts.

8.2.2. Operation time test

Setting values same as in preceding trip level test.

Decrease the phase current I_{L1} in fast step from 4,0 A to 3,0 A.

The operation time including the inertia of the output relay should be within $\pm 150 \text{ ms}$: 0,85 .. 1,15 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

8.3. Thermal protection stage T> (49)

The thermal overload function protects the line or protective object against thermal overload. The measuring is based on the RMS (Root Mean Square) value of the phase currents from which the heating of the cable to be protected is calculated.

Thermal stress can be supervised by means of a thermal image. The thermal image can be calculated from the standard heating expression according to IEC 60255-8:

Equation 8.3-1

$$t = \tau \cdot \ln \frac{I^2 - I_P^2}{I^2 - (kI_N)^2}, \quad \text{where}$$

| | | |
|----------------|---|---|
| T | = | heating time constant |
| ln | = | natural logarithm |
| I | = | measured phase current (injected current) |
| I _P | = | preload current |
| k | = | thermal overload current factor |
| I _N | = | nominal current |

Time to reach relative temperature Θ (alarm time) is according the cold start temperature model

Equation 8.3-2

$$t = \tau \cdot \ln \left(\frac{I^2}{I^2 - \Theta(kI_N)^2} \right), \quad \text{where}$$

Θ = relative temperature (alarm value % from trip value)

The heating time constant (τ) and the thermal overload current factor (k) corresponding to the maximum thermal load are settable. The factor k defines the load current value which, when exceeded, results in a thermal trip. The stage is also provided with a settable alarm function, the setting range of which is from 60 to 99% of the thermal trip level.

Connection for thermal overload test is same as in overcurrent protection test. When single phase testing device is used connect the secondary injection to IL1, IL2 or IL3 input. When three-phased testing device is used connect the secondary injection in all three inputs IL1, IL2, IL3.

If network designer information is available it is wise to use these values. But this chapter also includes example values which can be used in testing.

8.3.1. Trip level and operation time test

Setting values for relay testing must be marked in commissioning report site, setting values for thermal protection stage T>. Results of the test must be marked in commissioning report site, results for thermal protection stage T> test.

First set the injected current to zero amps and force the calculated temperature equal to 0,0%.

Example values for operation time test:

$$\begin{aligned}\tau &= 2 \text{ min} \\ I &= 2,0 \text{ A (injected current)} \\ I_P &= 0 \text{ A} \\ k &= 1,3 \text{ (same as maximum continuous current in VAMPSET)} \\ I_N &= 1,0 \text{ A} \\ \Theta &= 0,6 \text{ (60\%)}\end{aligned}$$

Time to the 60% alarm at temperature Θ_{alarm} according to Equation 8.3-2 will be:

$$t = 2 \cdot \ln\left(\frac{2^2}{2^2 - 0,6 \cdot (1,3 \cdot 1,0)^2}\right) = 0,5847 \text{ min} = 35,08 \text{ s}$$

Operation time to 60% alarm should be within $\pm 5\%$: 33,33 .. 36,84 s.

Operation time to 100% trip according to Equation 8.3-1 will be:

$$t = 2 \cdot \ln\frac{2^2 - 0^2}{2^2 - (1,3 \cdot 1,0)^2} = 0,549 \text{ min} = 65,88 \text{ s}$$

Operation time to 100% trip should be within $\pm 5\%$: 62,59 .. 69,18 s.

Mark the calculated alarm time and calculated operation time to commissioning report. Check that measured operation time and alarm time is inside the margin.

8.4. Reverse power and underpower protection stage P> (32)

Reverse power and underpower function is sensitive to active power. For reverse power function the pick up value is negative. For underpower function the pick up value is positive. Whenever the active power goes under the pick up value, the stage picks up and issues a start signal. If the fault situation stays on longer than the delay setting, a trip signal is issued. The pick up setting range is from -200% to +200% of the nominal apparent power S_n . The nominal apparent power is determined by the configured voltage and the current transformer values.

Equation 8.4-1

$$S_n = V T_{\text{Rated Primary}} \cdot C T_{\text{Rated Primary}} \cdot \sqrt{3}$$

8.4.1. Trip level test

When testing trip level of reverse power we have to inject voltage which phase angle is 180° to input U_{12} . 180° phase angle can be made by swapping the wires (when single phase testing device is used). When single phase testing device is used current must be injected in input $IL1$, that relay can calculate reactive power.

Example values for trip level test:

$$U_{VTPri} = 11000 \text{ V}$$

$$U_{VTSec} = 100 \text{ V}$$

$$I_{CTPri} = 500 \text{ A}$$

$$I_{CTSec} = 1 \text{ A}$$

$$P_{Set} = -10\%$$

$$t = (\text{Set definite operation time to it's minimum to make test easier})$$

$$U_{INJ} = 100 \text{ V} \angle 180^\circ \text{ (Same voltage value as } U_{VTSec} \text{ including } 180^\circ \text{ phase angle)}$$

When preceding values are used, the power which starts the protection stage according to Equation 8.4-1 is:

$$S_{Set} = 11000\text{V} \cdot 500\text{A} \cdot \sqrt{3} \cdot -0,1 = -952,6 \text{ kW}$$

Injected current which starts protection is calculated by following equation:

Equation 8.4.1-1

$$I_{INJ} = -P_{Set} \cdot \sqrt{3} \cdot I_{CTSec}$$

$$I_{INJ} = 0,1 \cdot \sqrt{3} \cdot 1\text{A} = 0,173\text{A} \angle 0^\circ$$

Relay should pick up within $\pm 3\%$: 0,168 .. 0,178 A.

Mark the setting values and test results in commissioning report, and check that results are inside the margin.

8.4.2. Operation time test

$$t = 1,0 \text{ s}$$

$$I_{INJ} = 2 * I_{Pick Up} = 2 * 0,173 = 0,346 \text{ A}$$

Other values same as in trip level test

Operation time including the inertia of the output relay should be within ± 150 ms: 0,85 .. 1,15 s.

Mark the setting value of operation time and test measured time in commissioning report, and check that result is inside the margin.

8.5. Undercurrent protection stage I< (37)

The three-phase undercurrent unit measures the fundamental frequency component of the phase currents. The stage I< can be configured for definite time characteristic. When single phase testing device is used IL1, IL2 and IL3 inputs must be connected in series (see Figure 8.5-1).

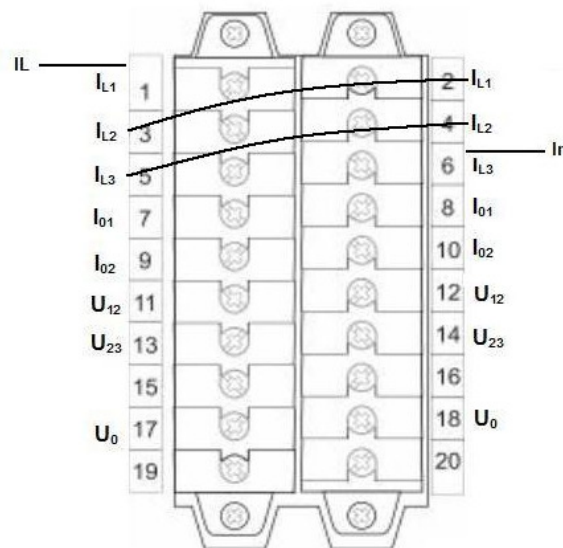


Figure 8.5-1 Single-phase connection for undercurrent testing

8.5.1. Trip level test

Use networks designer values if those are available. If those are not available use following example values.

Example values for trip level test:

$$I_N = 500 \text{ A}$$

$$I_{SET} = 50 \% \times I_N$$

$$t = 0,3 \text{ s} \text{ (Set definite operation time to its minimum to make the test easier)}$$

$$I_{SET} = 250 \text{ A}$$

$$I_{CTSec} = 1 \text{ A}$$

$$I_{INJ} = 0,5 \text{ A}$$

The actual pick up current should be within $\pm 2\%$: 0,49 .. 0,51 A. To find out the actual pick up level start with the current 0,55 A. Then slowly decrease the current until the stage starts.

Mark the setting values and pick up values in the commissioning report.

8.5.2. Operation time test

Example values for operation time test:

$I_{SET} = 0,5 \text{ A}$

$t = 1,0 \text{ s}$

Inject 0,55 A current to the relay. Decrease the current in fast step from 0,55 A to 0,45 A.

The operation time including the inertia of the output relay should be within $\pm 150 \text{ ms}$: 0,85 .. 1,15 s.

Mark the setting value of operation time and measured operation time to the commissioning report.

8.6. Arc fault protection stage ArcI> (50ARC)

The arc fault protection has been realised with arc sensor inputs and an extremely fast overcurrent function ArcI> or the earth fault functions ArcI0> and ArcI02>.

The arc protection function operates when one of the arc sensors detects an arc fault. The arc protection function operates also when the binary input of the arc option card is activates and the fast overcurrent stage ArcI> measures an overcurrent, or the earth fault stage ArcI0> or ArcI02> measures an earth fault at the same time.

Arc option testing is simple, inject the overcurrent or earth fault current to the relay and at same time give the bright light to the arc sensor. Relay should trip then if the arc option is enabled.

Light to the arc sensor must be bright and long enough. Bright flashlight is possibly the best solution for a light source.

8.6.1. Operation time test

Operation time in Arc-option is very fast 20 ms. One method to test the operation time is to give at first bright light to the Arc-sensor. While light is on, give $4x I_{NOM}$ overcurrent or earth fault current to the relay. Measure the operation time as in testing of overcurrent stages, from the beginning of injection to the trip.

Notice that if the light to the arc-sensor is on over 10 seconds, relays self supervision thinks that arc-sensor is faulty. So when the light is switched on as in preceding method, you have to inject the overcurrent or earth fault current to the relay input in under 10 seconds.

Operation time in arc-option with $4x I_{NOM}$ overcurrent or earth fault current should be under 22 ms.

When arc option is tested mark OK to the commissioning report.

9. Motor protection stages

This chapter describes methods of testing Vamp 255 motor protection stages. Notice that device must be turned in motor protection mode if these stages are used. There are also some pre-calculated values which can be used in testing.

9.1. Stall protection $I_{ST}>$ (48)

The stall protection unit $I_{ST}>$ measures the fundamental frequency component of the phase currents. Stage $I_{ST}>$ can be configured for definite time or inverse time operation characteristic.

The stall protection stage protects the motor against prolonged starts caused by e.g. a stalled rotor. While the current has been less than I_{STOP} and then within 200 ms exceeds $I_{StartMin}$ the stall protection stage starts to count the operation time T according to Equation 9.1-1. When current drops below $120\% \times I_{MOT}$ the stall protection stage releases.

Equation 9.1-1

$$T = \frac{I_{START}}{I_{MEAS}} T_{START}, \text{ where}$$

- T = Operation time
- I_{START} = Start current of the motor. Default $6,00 \times I_{MOT}$
- I_{MEAS} = Measured current during start
- T_{START} = Maximum allowed start time for the motor

9.1.1. Operation time test

When inverse time operation is used, operation time must be calculated according to Equation 9.1-1. Following example values can be used in testing if actual values are not available.

Example values for operation time test:

- I_{CTPri} = 500 A
- I_{CTSec} = 1 A
- I_{MOT} = 400 A
- I_{START} = $6,00 \times I_{MOT} = 2400$ A
- I_{MEAS} = $2500 \text{ A} / 3 = 833$ A (when single-phase testing is used)
- T_{START} = 2 s (same as inv. time coefficient k in VAMPSET)
- I_{INJ} = $I_{MEAS} / I_{CTPri} = 2500 \text{ A} / 500 \text{ A} = 5$ A

Let's calculate inverse operation time. Inverse operation time according to Equation 9.1-1 will be

$$T = \frac{2400A}{833A} \cdot 2s = 5,76 \text{ s}$$

Inject the current of 5 Amps to relay current input IL1, IL2 or IL3. Operation time should be within $\pm 5\%$: 5,47 s .. 6,05 s.

Mark calculated value and measured operation time in commissioning report and check that value is inside the margin.

9.2. Phase reversal / incorrect phase sequence protection $I_2 \gg$ (47)

Phase reversal protection can be tested only with three-phase testing device!

The phase sequence stage prevents the motor from running in the wrong direction, thus protecting the load. When the ratio between negative and positive sequence current exceeds 80%, the phase sequence stage starts and trips after 100 ms.

Functionality of this stage is same as in unbalance stage. So the equations for this stage is as in chapter 8.2.

9.2.1. Operation time test

In this stage the pick up setting and operation time are constant. Pick up setting is 80% and operation time 100 ms.

Testing of operation time can be done by swapping two relay phase currents. When this is done inject the current to the relay and measure operation time.

Operation time should be < 120 ms. If that is correct mark OK in commissioning report site Phase reversal test.

10. Reference information

Manufacturer & Service data:

VAMP Ltd

P.O.Box 810

FIN-65101 Vaasa, Finland

Visiting address: Yrittäjänkatu 15

Phone +358 (0)20 753 3200

Fax. +358 (0)20 753 3200

Email: vamp@vamp.fi

URL: <http://www.vamp.fi>

24h support phone:

Tel . +358 (0)20 753 3200

Email: vampsupport@vamp.fi



We reserve the rights to changes without prior notice

VAMP Ltd

Street address: Yrittäjänkatu 15
Post address:
P.O Box 810, FIN 65101 Vaasa,
Finland

Phone: +358 20 753 3220
Fax: +358 20 753 3205
Internet: www.vamp.fi
Email: vamp@vamp.fi