RefleX² Protection and Control

RefleX² - 231

Differential protection for two-winding
and three-winding transformers
Restricted Earth Fault Protection

2W/3W differential protection
REF protection
Model 231

Jacobsen Elektro

Application

The RefleX differential relay is designed to protect high voltage two-winding and three-winding transformers
It can also protect small generators and busbars with up to 3 branches. The relay is extremely easy to use
and its setting tools and menus are especially designed to enable easy setting and quick, cost-efficient operation.

Measurement

The two-winding transformer differential protection is formed by two RefleX units. Three-winding differential relays
are formed by three Reflex units. The measured values are transmitted between the units through optical fibres.
An inrush-current measurement is restraining the trip function during the energisation of the transformer.
The currents are measured and the 1st, 2nd and 5th harmonic and extracted by fourier analysis.

REF function (independent of communication)

Local restricted Earth-Fault measurement between EF connection in the transformer neutral point current.
Stabilized differential current prinsiple, low impedance type.
This function is operating independently of all other input modules, and is active even if the differential.
function is disabled by communication error.

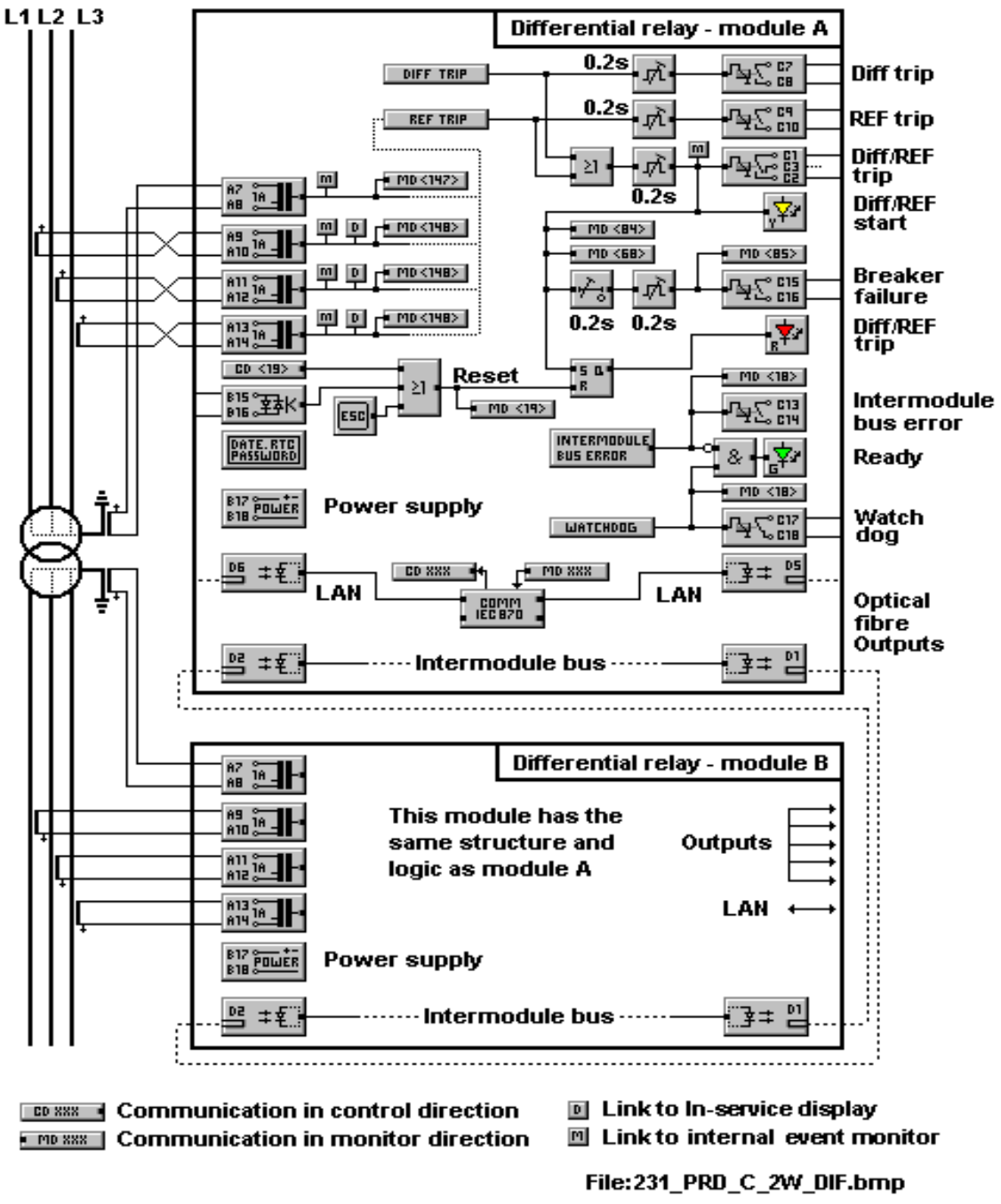
Watchdog (system supervision)

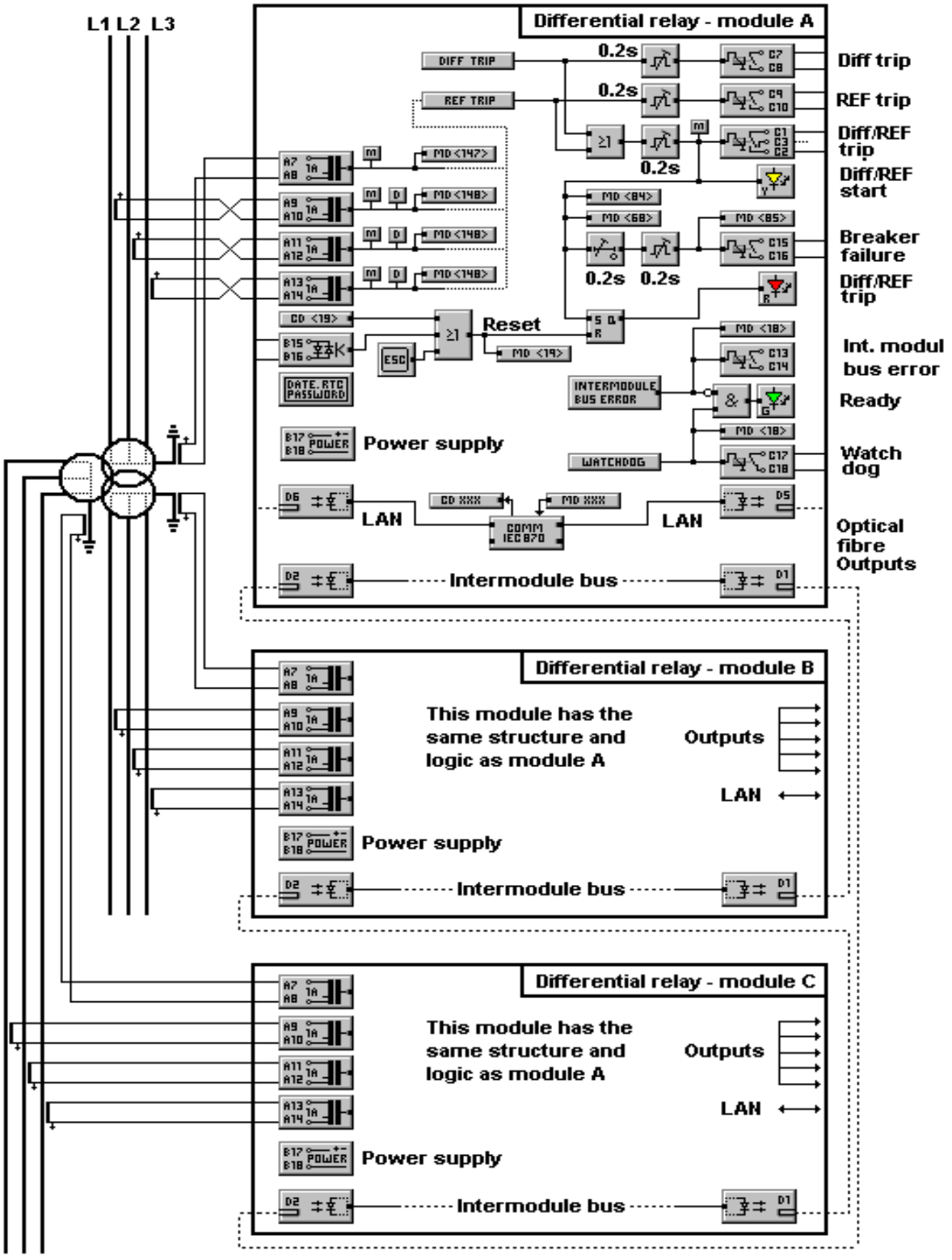
The supervision function will alert the user by turning the green LED off and by closing the WD contact (C17-C18):

- when power supply is interrupted for more than 100ms
- when a fault occurs in one or more of the relay processors or memory.

Intermodule Communication Supervision

When there is an error in the optical fiber connection between the relay modules, then the supervision function
will turn the green LED off and close the Intermodule-Bus Error contact (C13-C14). This enables the user to
distinguish between internal errors, and errors in the external fiber connections.
In this case the REF function will still be active, although the REF trip signals cannot be distributed along the
faulted or missing optical fibers to the other diff modules.


L1 L2 L3
Differential relay - module A
DIFF TRIP
REF TRIP
0.2s
Diff trip
REF trip
Diff/REF trip
Diff/REF start
Breaker failure
Diff/REF trip
Intermodule bus error
Ready
Watch dog
Optical fibre Outputs
Reset
Power supply
LAN
LAN
Intermodule bus
Differential relay - module B
This module has the same structure and logic as module A
Outputs
LAN
Power supply
Intermodule bus
Communication in control direction
Communication in monitor direction
Link to In-service display
Link to internal event monitor
File:231_PRD_C_2W_DIF.bmp


L1 L2 L3
Differential relay - module A
DIFF TRIP
REF TRIP
0.2s
Diff trip
REF trip
Diff/REF trip
Diff/REF start
Breaker failure
Diff/REF trip
Reset
ESC
DATE. RTC PASSWORD
Power supply
INTERMODULE BUS ERROR
Int. modul bus error
Ready
WATCHDOG
Watch dog
LAN
COMM IEC 870
Optical fibre Outputs
Intermodule bus
Differential relay - module B
This module has the same structure and logic as module A
Outputs
Differential relay - module C
Communication in control direction
Communication in monitor direction
Link to In-service display
Link to internal event monitor
File:231_PRD_C_3W_DIF.bmp

Setting menu

(The values in this page are only informative examples, not recommended settings)

`Diff. Module A`
`IL1 124A`
`IL2 120A`
`IL3 123A`
	A separate description of alternative read-outs from the display is found in another section of this document	In-service display (default display)
		Displaying current in phase 1
		Displaying current in phase 2
		Displaying current in phase 3

`Trip records`	A separate description of the sub-menu "Trip Records" is found in another section of this document	Press "enter" here to display stored trip records After selecting a record use "arrow up" or "arrow down" to display additional information. Leave sub-menu by pressing "Esc".

`Input references`
`This is module A`
`Voltage 132kV`
`CT 500/5A In5A`
		Data related to each input (module)
		Designate: Module A, Module B, (Module C)
		Rated voltage (reference) for power transformer
		CT ratio and rated relay current for this winding

`Transformer data`
`Ref.pwr. 100MVA`
`Vectors A-B-C:`
`YN-yn0-d11`
		Power transformer data.
		Usually rated power for the "primary winding"
		Power transformer vectors are specified here
		in module A (mirrored to module B / C)

`Diff. trip curve`
`dI> 40%`
`Bias 40%`
`dI>> 500%`
		Low diff. Setting (mirrored to module B/C)
		Bias slope setting (mirrored to module B/C)
		Unrestrained high diff. (mirrored to B/C)

`REF On Mod.A`
`Voltage 132kV`
`IREF 10/0.1A`
`CT 100/1A In1A`
		***) Please observe REF comment below**
		REF on/off Module name
		Reference voltage
		REF trip level referred to neutral-point CT (Ig)
		Neutral-point CT ratio Relay rated current

`Harmonic Block`
`H2 20%`
`H5 40%`
		Harmonic blocking function
		2. Harmonic blocking setting
		5. Harmonic blocking setting

`Common #1`
`CB fail backup:`
`tCBF 0.2s`
		Common settings for the complete relay
		Breaker failure function delay

`Comm. IEC ON`
`Config Star`
`Address 45`
`Meas. Value 1.2`
		Communication parameters
		Ring/star On/off
		Relay address (1..254)
		Value of measurand

`YMD 2003-05-29`
`HMS 13:52:36`
`Password ****`
`Freq. 50Hz`
		Year - month - day
		24 hour clock
		Four-digit password (default 1111)
		Rated power system frequency

***) REF comment:**

If the communication between modules is broken, then the differential function is disabled, the green "OK indicator" in the relay front panel is turned "off" and a "communication error" message appears in the display. Although the green lamp is "off", the REF function is however still active, forming a backup during the time when the differential function is disabled.

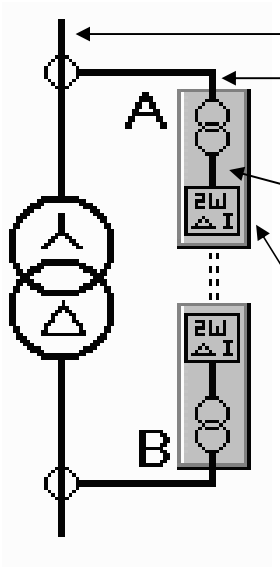
When the communication is out of service, the REF trip will not be distributed to the other units as usual. If it is required to trip all transformer breakers in that particular situation all trips should be hardwired enabling any trip signal from any unit to trip all transformer breakers.

In-service displays, and error messages

Selecting between the different In-service displays is done by pressing "enter" when the display is active.
Some of the displays are to be used mainly during commissioning. This is for instance the case for the differential currents. Under normal circumstances these values are of limited interest to the operational staff.
After pressing "Esc" the display will return to the initial display: primary phase currents.
This example is for a 2-winding transformer, displaying module A values.

Main menu:

Submenu, Displays:



	The measuring displays is part of the main menu. Those are selected by pressing "Enter" multiple times.
Diff. Module A IL1 124A prim. IL2 120A prim. IL3 123A prim.	Module identification line Measured primary phase currents. This display is the usual in-service display
Diff. Module A IL1 2.00A ∠ Ref° IL2 2.01A ∠-120° IL3 2.03A ∠+120°	Module identification line Measured secondary phase-currents and angles before compensating with apparent intermediate current transformers.
Diff. Module A Ic1 2.00A ∠ 0° Ic2 2.01A ∠-120° Ic3 2.03A ∠+120°	Module identification line Calculated compensated currents and angles after compensating with apparent intermediate current transformers.
Diff. current Id1 3% Id2 3% Id3 2%	Differential current in percent of reference values Differential current in percent of reference values Differential current in percent of reference values
Restricted EF Io 121A ∠ Ref° Ig 110A ∠-180°	Restricted earth measuring primary values Vectorial sum of phase currents (3Io) Measured current in transformer Y to ground connection
Communication error. Check intermodule fiber bus.	This display only appears when if is an error in the physical intermodule bus. Possible causes may be failures in: intermodule optical fibers, module hardware or module power supply.
Master module is not defined. Set one module name: A	This display only appears if none of the modules is defined as "A". The "A" module is the master unit where all common settings are done. The relay must have one "A" module.
The number of RefleX modules does not match Transf.Vectors	This display only appears if there is a mismatch between the number of RefleX modules and the transformer type (2W diff or 3W diff) that is set in the "transformer data / Vectors" display.
Name or connect modules in this way: A-B-C Present: A-B-C	This display only appears if module names are duplicated or out of sequence. Rename modules until the "present" line matches the suggested name-sequence (A-B or A-B-C)
Diff. module A Check current phase sequence	This display only appears when a "negative-sequence current" is measured. Indicates that the phase sequence is wrong (reverse rotating system)

Trip-records sub-menu

All displays show recordings subsequent to relay tripping. The last five recordings are always stored.
After a relay trip the display showing date and time of the trip automatically appears.
By using ENTER followed by arrow up/down the user may access all information in the displays below.
Each trip is automatically assigned a separate serial number
Only trip records (displays) with active information is stored and/or displayed after a trip.

```
Trip records
```

This display is part of the main menu
After selecting a record use "arrow up" or "arrow down" to display additional information.
Leave trip records by pressing "Esc".

```
Trip 333
 2001-12-24
 12:13:14.123
```

Header (in this case looking at trip no. 333)
"trip 333" date
"trip 333" time

```
Trip 333
 Differential*
 Restricted EF
 Remote Trip
```

Trip indication
Differential trip (indicated by a star)
Restricted Earth Fault trip (indicated by star)
Remote REF trip from other module (star)

```
Trip 333
 IL1   951A prim.
 IL2   120A prim.
 IL3   123A prim.
```

Primary fault currents
Fault current in phase L1.
Fault current in phase L2.
Fault current in phase L3.

```
Trip 333
 IL1 2.00A ∠ Ref°
 IL2 2.01A ∠-120°
 IL3 2.03A ∠+120°
```

Secondary fault currents
Secondary fault phase-currents and angles before compensating with the apparent intermediate current transformers.

```
Trip 333
 Restricted EF
 Io  0.00A ∠ Ref°
 Ig  0.00A ∠  0°
```

Measured Restricted Earth Fault trip data:
E/F Current - primary sum of phase currents (3Io)
E/F Current - primary measured in the neutral point

Connection tests - Differential functions (commissioning tests)

The operation of differential relays is based on Kirchoffs law: "at every node, the sum of all currents entering a node must equal zero". The differential protection is measuring the size and direction of all currents through the transformer. By calculating the vectorial sum of the currents it is possible to prove that the relay is properly configured and correctly connected to the transformers measuring system

During the tests below the transformer must be loaded to at least 10% of its rated power.

Phase sequence

```
Diff. module A
Check current
phase sequence
```

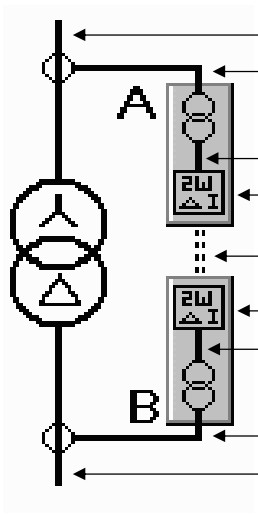
If the phase sequence is incorrect this message will automatically appear in the in-service-display on module A or B (or C if the differential relay is protecting a three winding transformer).

Modules and readouts

The RefleX differential relay consists of two (or three) relay modules. Each module measures the currents on one side of the transfomer The modules are named A, B (and C if the transformer has three windings). Module A is usually placed on the transformer high-voltage side, or on the side of the transformer that is usually loaded. Modules B and C are normally placed on the low voltage or medium voltage sides and communicate continously with each other through optical fibers.

Example data:

Transformer connection	Yd1
Transformer power	26 MVA
HV voltage	33kV
HV CT ratio	600/5A
LV voltage	11kV
LV CT ratio	1600/5A
Actual load	8.5 MVA
HV load current	148.7A
LV load current	446A




```
Diff. Module A
IL1   149A prim.
IL2   150A prim.
IL3   148A prim.
```

Transformer HV side display
Currents on the transformer HV-terminals (primary currents)

```
Diff. Module A
IL1 1.24A ∠ Ref°
IL2 1.25A ∠-120°
IL3 1.23A ∠+120°
```

Transformer HV side display
Secondary currents and angles measured on the transformer relay input terminals

```
Diff. Module A
Ic1 1.63A ∠   0°
Ic2 1.63A ∠-120°
Ic3 1.62A ∠+120°
```

Transformer HV side display
Secondary currents and angles after the relay has compensated for CT ratio and transformer data

```
Diff. current
Id1 3%
Id2 3%
Id3 2%
```

Transformer HV side display
Differential current. The percentage is referred to the transformer load current.

```
Diff. Module B
IL1   446A prim.
IL2   445A prim.
IL3   446A prim.
```

Transformer LV side display
Currents on the transformer HV-terminals (primary currents)

```
Diff. Module B
IL1 1.38A ∠+210°
IL2 1.39A ∠ +90°
IL3 1.39A ∠ -30°
```

Transformer LV side display
Secondary currents and angles measured on the transformer relay input terminals

```
Diff. Module B
Ic1 1.62A ∠+180°
Ic2 1.62A ∠ +60°
Ic3 1.61A ∠ -60°
```

Transformer LV side display
Secondary currents and angles after the relay has compensated for CT ratio and transformer data

```
Diff. current
Id1 3%
Id2 3%
Id3 2%
```

Transformer LV side display
Differential current. The percentage is referred to the transformer load current.'

Confirming the connections and relay parameters

By studying the displays the direction of the phase measurements may be confirmed, using the Ic1, Ic2 and Ic3 values (phase currents) :

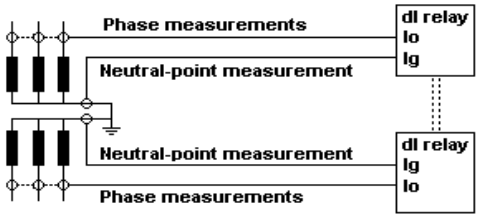
* Calcuate the vectorial sum of all the Ic1 currents measured by modules A, B (and C). Repeat the calculation using Ic2 and Ic3 data. If the three resulting currents are close to zero (less than 5% of the load current), then the connections are correct, and the parameters set on the relay modules match the actual transformer data.
* Crosscheck the calculations and conclusions above by reading the Diff. Currents Id1, Id2 and Id3. Less than 3% diff current indicates correct connections and correct transformer data in the relay modules.

Connection tests - Restricted Earthfault functions (commissioning tests)

The Restricted-Earth-Fault function (REF) only operates reliably when there is a minimum of earth-fault current available during earth-fault in the protected power transformer. The function is therefore disabled or not operational in many power systems with ungrounded or high-impedance-grounded neutral connections.

Principle of measurement

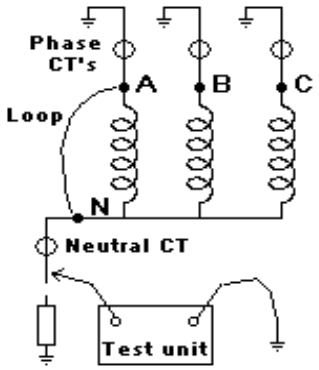
The principle of this function is to compare the zero sequence current measured in the transformer phase terminals with the zero sequence current measured directly in the transformer neutral connection. Because these currents are only present during system disturbances, the connections and the relay parameters must be verified by injecting a test current into the primary circuit.



The REF function in a RefleX relay measures zero-sequence current in each relay module using the sum of the phase currents. This value is named Io (zero sequence current) in the in-service-display of the RefleX relay module.
The current in the neutral-to-ground connection is measured and is named Ig (ground current) in the in-service-display of the RefleX relay module.

Test procedure

This procedure is not valid if the protection is connected to current transformers in the power transformer bushings.
To test the REF function in such transformers a primary current test equipment is needed.



* The power transformer is grunded in all three phases beyond the phase CT's located in the switchgear cubicle. This is usually done by closing the earthing switch located in the switchgear cubicle.
* A 10mm2 cable loop is connected between the power transformers neutral terminal and one of the phase terminals (A-N in the illustration).
* The power transformers neutral connection to ground is opened
* A test unit capable of supplying 100A test current is connected to the power transformer neutral "below" the location of the neutral current transformer. A Sverker 760 test equipment is usually suitable for the current injection.
* After testing the N-A values, the loop is moved to N-B and the test is repeated. Finally the loop is moved to N-C and the test repeated.

Test evaluation

```
Restricted EF
 Io  121A  ∠  Ref°
 Ig  110A  ∠-180°
```

During an injection test the values measured by each relay module is displayed in the in-service display of the relay:

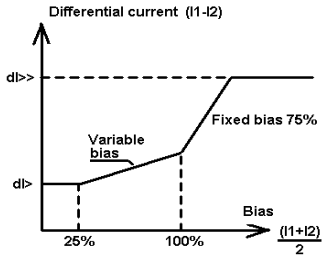
* If the displayed Ig angle is close to 0 degrees, or if the relay trips by the REF-function, then the polarization of the Ig circuit must be reversed. Angles near the values of +180 degrees or -180 degrees both indicate correct connections.
* If more than 3% difference between the measured Io and Ig currents is observed then there is a fault in at least one of the measurements (CT ratio error, shorted terminals, open current circuits etc).

Technical data

Differential module

Low differential current setting	dI>	10.0-100 % and ∞
High differential current seting	dI>>	200-2000% and ∞ (unrestrained)
Variable bias setting	Ibias	10.0-60.0 %
Min operating current		0.1 * In
Max operating current		75 * In
Typical trip time		38 ms (50 Hz system frequency)
Typical reset time		38 ms (50 Hz system frequency)
2.harmonic blocking setting	H2	10.0-100 % and ∞ of 1. Harmonic
5.harmonic blocking setting	H5	10.0-60.0 % and ∞ of 1. Harmonic

Characteristic



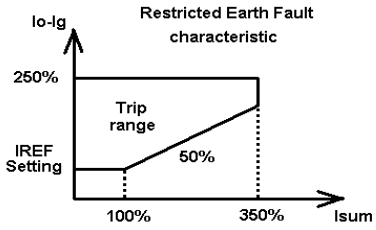
Restricted Earth Fault protection (REF protection)

Restricted Earth Fault trip level	IREF	0.10-1.0 A and ∞ (Ino = 1A)
	IREF	0.50-5.0 A and ∞ (Ino = 5A)
		(Settings referred to relay neutral point input)
Min operating current		0.1 * In (referred to relay neutral-point input)
Max operating current		2.5 * In (referred to relay neutral-point input)
Typical trip time		45 ms (50 Hz system frequency)
Typical reset time		45 ms (50 Hz system frequency)

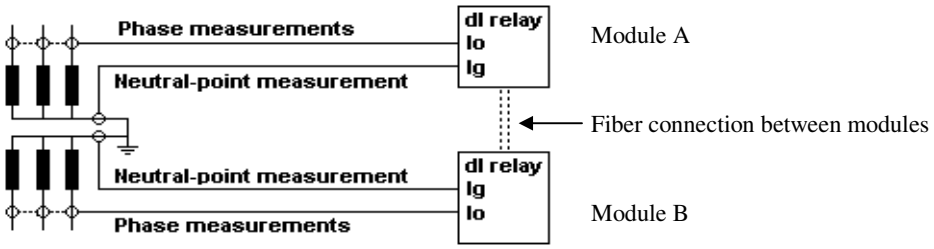
Characteristic

(Io-Ig and Isum in % of nominal current:)

Io = vectorial sum of phase currents IL1+IL2+Il3
Isum = sum of phase current amplitudes (IL1+IL2+Il3)/3
Ig = measured current in transformer Y-to-ground



Connection references



Rated data for Protected Primary Unit (usually a transformer)

Reference power (Pref)	Ref. Power	0.5-500 MVA (Usually = Pn for HV winding)
Vector group	Vectors	Y or D connections in 30 degrees steps
Primary voltage (Un) for all sides	Voltage	0.2-999 kV (Tap changer in center position)

System

Module reference on HV, MV, LV sides	Module	A, B, C
Frequency		50 Hz
Factory default password		1111
Pulse extension circuit at all trip outputs		0,2 s

Intermodule bus supervision

Message after bus failure	Module	A, B, C: error message and trip block

Communication (IEC 60 870-5-103 protocol)

Configuration system	Star or Ring
Address of protection equipment	1 to 254
Value of measurand (x In)	1.2 or 2.4
Optical fibre transmitters	Outputs D3,D5
Optical fibre receivers	Inputs D4,D6

Selection of standard information numbers (IEC 60870) in monitor direction (MDxxx)

Protection inactive (internal fault)	<18>
LED-reset	<19>
General trip	<68>
General start	<84>
Breaker failure	<85>
Measurands IN	<147>
Measurands IL1,2,3	<148>

Selection of standard information numbers (IEC 60870) in control direction (CDxxx)

LED-reset	<19>

Circuit Breaker Failure Protection (CBFP)

Trip transfer delay. Recommended setting = 0.2s	0.15 - 9.99 s