Common Format for IED Configuration Data

A report to the Power System Relaying Committee of the IEEE Power Engineering Society

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1 Abstract

Since the era of electromechanical relays, different relay manufacturers are using the same principles to develop protection devices to protect elements of the power system. For example, principles based on overcurrent, differential current, or calculations of the distance to the fault are the most common, which almost each manufacturer offers in its portfolio. However, even though the principles used are the same, the configuration data used to configure the functions seem to be different for each manufacturer. The complexity of difference can be classified as follows:

1. Use of different name conventions. The same settings with the same meaning are named differently by different relay manufacturers.
   Example: Time Over current pick up setting
   - Ip
   - 51 Pickup
   - TOC

2. Different meanings for the same name. In this case manufacturers use settings with the same name to set a certain behavior but interpret the values differently.
   Example: R-reach of quadrilateral ground distance characteristic
   - Resistive reach before zero sequence compensation (loop resistance)
   - Resistive reach after zero sequence compensation
   - Resistive reach as additional fault resistance (excluding line resistance)

3. Different settings because of different unique solution algorithms. These are settings which may be unique or used by only some manufacturers because of a unique solution approach.

The goal of this report is to evaluate the possibility of defining a common format for IED configuration data. This common format should allow the exchange of configuration data between different applications like coordination programs, test programs, databases, and setting software. In many numerical relays, programmable logic is also part of the IED configuration. For this report the programmable logic is excluded and needs to be addressed later. The report will focus only on one medium complexity function, the distance protection function (IEEE C37.2, Function 21), to prove whether the goal is achievable or not. The working group assumes that if a common format for a distance protection function can be described, then all other protection functions can be modeled as well.

2 Task

A common format for IED configuration data should be defined. The configuration data described in this common format should allow only one unique interpretation for use in a given application. The format must be powerful enough to convert any practical IED configuration into this format. The conversion from this common format into a specific IED configuration data set depends on the ability of the IED to support the described application requirements and may not be possible in all cases. The common format can be used to exchange IED data between different data sources and receivers. Sources and receivers can be IED configuration programs, network study programs, databases, coordination programs, and automated test programs.

3 Introduction

The working group decided to focus on the distance protection function because this particular function includes sufficient complexity to rigorously test the approach for standardizing the settings of the function. The function is one of the most frequently used functions in the transmission network and is equally common across the world. However, the implementation of the function has seen quite an evolution starting in the electromechanical age up to the numerical relays today. Also it can be observed that the implementation of the function is different in different regions as well. If a standard setting representation can be given for a distance protection function, it should be possible to standardize the settings of any protection function.

4 Example: Distance Protection

The distance protection function is often not used as a step distance function and interacts with other functions. Examples are functions which are used to block the distance function under certain conditions like power swing blocking, fuse failure monitoring etc. or functions which enhance the distance function like pilot schemes. For this report we did not include such supporting functions and focused only on the plain distance function, even though there is a gray area where it is debatable whether a function is part of the distance function or not.

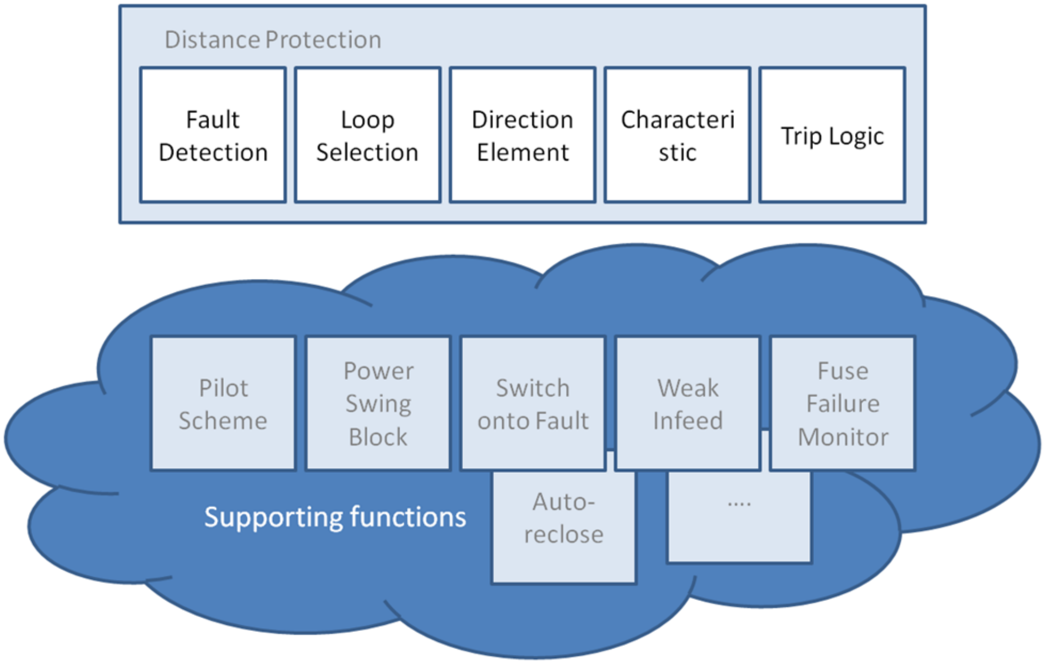


Figure 4.1 Overview of sub function and supporting functions for Distance Protection

Looking at a distance protection function, it becomes obvious that it consists of several components, where some of these components are used as well as other independent functions. For example, in many distance relays an overcurrent pick-up function is used for fault detection. In these situations, the working group is going to reference the appropriate function and will not attempt to give a specification in this report.

In the following sections, the report will give an overview on settings which are candidates for standardization. Each of the standard blocks shown in figure 4.1 will be discussed.

This report uses the already existing naming convention and terminology introduced by IEC61850, but does not require that the IED be IEC 61850 compliant. The working group envisions that a future standard for IED configuration based on this report will accommodate both IEC 61850 and non-IEC 61850 IEDs, but an aligned with IEC61850 will be more readily accepted worldwide and cause the expansion of IEC61850 definitions where needed to facilitate the technique.

This report uses the following names for protection functions / logical nodes as introduced in IEC61850-7-4

Protection Function	IEEE C37.2 Function number	IEC61850 Logical node
Distance protection	21	PDIS
Instantaneous Over current protection	50	PIOC
Time Overcurrent	51	PTOC
Under voltage	27	PTUV
Voltage controlled time overcurrent	51/27R	PVOC

For the standard format we are proposing to use primary values.

4.1 General

On almost all numerical relays, there are settings which will set the whole distance function in a certain operating mode. The working group would standardize for this purpose the following two configuration settings:

PDIS.Config

For the whole distance protection function, there is one Enable/Disable switch available for the main configuration inside a multifunctional relay. The switch has the function to make the function existent inside the relay. If the setting is on disabled, no other reference of the function (settings, alarms) is visible in the relay.

Name: PDIS.Config
Type: Boolean
Values: Enable/Disable

PDIS.Mod

The PDIS.Mod is a general switch setting which allows switching of the function on or off. If the setting is on “off”, the distance protection function will not be processed. All settings and other references to the function are visible.

Name: PDIS.Mod
Type: enumerated list
Values: On/Off/Blocked

4.2 Fault Detection

In many cases the distance/impedance calculation and evaluation is not done continuously but rather is started by fault detection criteria. The most common fault detection criteria are already defined as separate functions and need only to be referenced here. Based on the result of the fault detection, certain impedance loop calculations and evaluations are started. The selection of particular loops based on the fault detection result is dependent on logic which is not modeled here and may be different for different implementations. Settings which are used to influence the loop selections are introduced in the section 4.3 “Loop Selection”.

PDIS.PUMth

PDIS.PUMth selects which fault detection method is enabled and used to start an impedance loop calculation. The method could be different for the distance ground and the distance phase element.

Name: **PDIS.PUMth**
Type: enumerated list
Values: PIOC/ PTOC/ PTUV/ PVOC/ PDIS

It is assumed that all selectable fault detection functions are already defined outside of this document and need only to be referenced here. Even though not all settings may be defined for these functions at this time, the reference still is valid. The completion of the setting definition needs to take place in these referenced functions.

PDIS.PUStr

The setting PDIS.PUStr selects whether the fault detection will start the timer of all zones or only the zone timer which sees the fault impedance in its zone. This is relevant for faults where the fault impedance moves during the fault from one zone into another one.

Name: **PDIS.PUStr**
Type: enumerated list
Setting: All Timer/ Zone Timer

4.3 Loop Selection

After the fault detection, a distance relay has to select the loops which should be considered for fault evaluation. In many instances, this is fixed logic inside the IED and cannot be influenced via settings. In the following, settings are identified which are available on some products to influence the loop selection.

PDIS.FltLoop2phMth

If a phase-to-phase-to-ground fault was identified by the fault detection, it may not be desirable to process all possible 3 loops as the leading phase to ground loop tends to overreach. The PDIS.FltLoopMth setting determines which of the loops should be calculated.

Name: **PDIS.FltLoopMth**
Type: enumerated list
Values: Block leading phase/
Block lagging phase/
only phase-phase/
only phase-ground/
all

PDIS.FltLoop3phMth

If a three phase-to-ground fault was identified by the fault detection, it may not be desirable to process all possible 6 loops. The PDIS.LOOP.3PG setting determines which of the loops should be calculated.

Name: PDIS.LOOP.3PG
Type: enumerated list
Values: only phase-phase/
only phase-ground/
all

4.4 Distance Zone

A distance zone is used to classify the calculated fault impedance as inside or outside a protection zone. Normally an IED has several zones, each of which is used for different purposes. The settings used to set a distance zone consist of the following main components:

- General setting, enabling or disabling the zone for certain situations
- Characteristic
- Direction
- Special treatments for ground elements

4.5 General Distance Zone Setting

PDIS.ZnMod

Each zone has a general setting which allows switching the zone on, off or to a blocked status. If the setting is “off”, the distance protection function will not use the zone for any protection purpose. All settings and other references to the zone are visible. The “blocked” position will cause the distance zone to process normally but prevent the tripping of the zone.

Name: PDIS.ZnMod
Type: enumerated list
Values: On/Off/Blocked

PDIS.ComMod

Each zone can be Enabled or Disabled depending upon the status of the communication channel. The purpose is to give, for example, the current differential relay the preference against a distance zone. If the communication channel is not working, and for this purpose the current differential function is blocked, the zone can be enabled. If the switch is on Disabled, the zone is blocked if the communication channel is working. If the switch is on enabled, the communication channel has no influence on the zone. The zone would be always active.

Name: PDIS.ComMod
Type: Boolean
Values: Enable/Disable

PDIS.PSMod

Each zone can be blocked in a power swing situation. If the setting is on "blocked", the zone will not issue a trip command even if the impedance is inside the zone and the zone timer has elapsed. Whether the zone timer starts or not is manufacturer dependent.

Name: PDIS.PSMod
Type: Boolean
Values: blocked/normal

PDIS.ArcMod

A zone can be accelerated if an autoreclose function exists and ready to reclose after a trip (not a final trip) or closes the tripped breaker after a settable dead time (close onto a fault). If the setting is on "1. Trip", the zone will issue a trip command instantaneously if the autoreclose function is ready to reclose the breaker. If the setting is on "After reclose", the zone will issue a trip command instantaneously if the autoreclose function just reclosed the breaker. If the setting is on "always", the zone will issue a trip command instantaneously if the autoreclose function is ready to reclose the breaker or after a reclose onto a fault. If the setting is on "normal", the behavior of the zone will be independent of an autoreclose function.

Name: PDIS.ArcMod
Type: enumerated list
Values: 1. Trip/ after reclose/ always /normal

PDIS.FuFailMod

Each zone can be blocked if a blown fuse is detected via a so called fuse failure monitor (FFM). If the setting is on "blocked", the zone will not issue a trip command even if the impedance is inside the zone and the zone timer has elapsed. Whether the zone timer starts or not is manufacturer dependent.

Name: PDIS.FuFailMod

Type: Boolean
Values: blocked/normal

PDIS.SwFltMth

A zone can be accelerated if a fault right after the closing of a breaker is detected (switch onto a fault). If the setting is on “accelerate”, the zone will issue a trip command instantaneously if a switch-onto-fault monitoring logic signals the monitoring time is running and an impedance is measured inside the zone characteristic.

Name: PDIS.SwFltMth
Type: Boolean
Values: accelerate/normal

PDIS.DirMod

The direction of the zone is set via the setting PDIS.DirMod

Name: PDIS.DirMod
Type: enumerated list
Values: forward/reverse/non directional

4.6 Characteristic

Non-Directional Circular Characteristic (Ohm)

The non-directional circular characteristic (also known as the Ohm characteristic) is the simplest impedance characteristic. The impedance reach setting defines an operational area which is a circle with a radius equal to the setting and center at the origin of the impedance plane.

Since many of the applications of distance protection require directionality, in many cases the Ohm characteristic is supervised by a directional element.

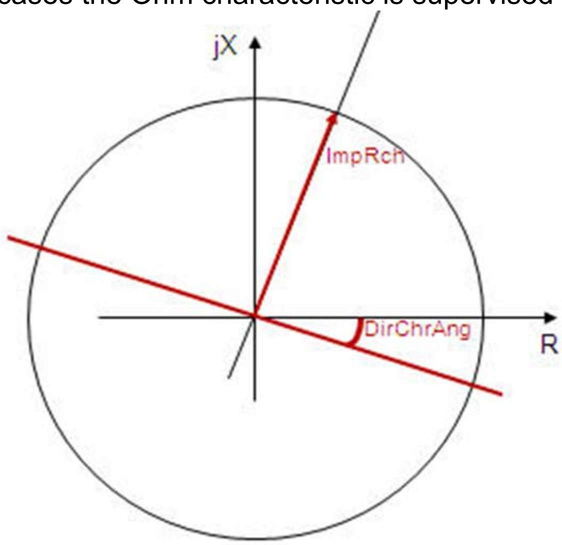


Figure 4.2 Ohm characteristic with directional supervision

PDIS.ImpRch

PDIS.ImpRch (impedance reach) is specified in primary ohms.
Name: PDIS.ImpRch
Type: float
Values: 0..999 [ohm prim]

PDIS.DirChrAng

PDIS.DirChrAng is specified as a clockwise angle measured from the R-axis.
Name: PDIS.DirChrAng
Type: float
Values: 0..180 [degree]

4.7 MHO

Mho characteristics are one of the most commonly used and can have several different attributes depending on the design. The shape of the characteristic to be tested depends on the setting attributes as well as the polarizing method used.
Most commonly used are self-polarized, cross polarized, memory polarized, and offset Mho characteristics.
While in conventional electromechanical relays the Mho characteristic is a circle, in microprocessor based relays the Mho circle is used with additional blinders in order to achieve better performance under different conditions.
The characteristic used here should accommodate all characteristics in use.

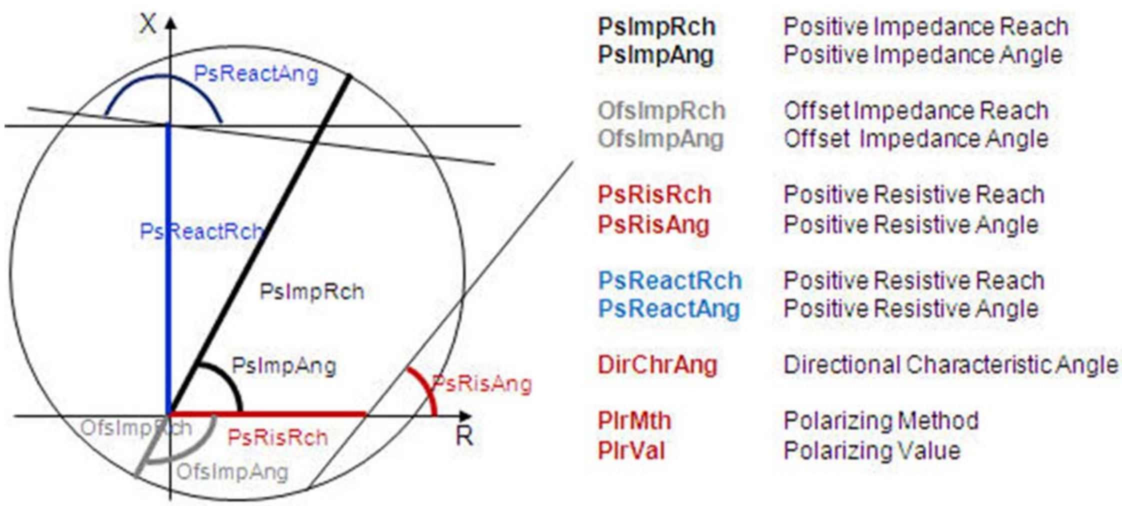


Figure 4.3 Mho characteristic

The polar reach defines the reach of the Mho circle and corresponds normally with the percentage of line impedance which needs to be protected by the zone. For Mho circles without offset, this represents the diameter of the circle. The reach is set with two parameters:

PDIS.PsImpRch

PDIS.PsImpRch (positive impedance reach) is specified in primary ohms.

Name: PDIS.PsImpRch
Type: float
Values: 0..999 [ohm prim]

PDIS.PsImpAng

PDIS.PsImpAng is specified as a counter-clockwise angle measured from the R-axis.

Name: PDIS.PsImpAng
Type: float
Values: 0..180 [degree]

4.8 Offset

For setting an offset on the Mho circle the two parameters OfsImpRch and OfsImpAng are used.

PDIS.OfsImpRch

PDIS.OfsImpRch (offset impedance reach) is specified in primary ohms.

Name: PDIS.OfsImpRch
Type: float
Values: 0..999 [ohm prim]

PDIS.OfsImpAng

PDIS.OfsImpAng is specified as a clockwise angle measured from the R-axis.

Name: PDIS.OfsImpAng
Type: float
Values: 0..180 [degree]

4.9 Blinders

In some relays the Mho characteristic is combined with blinders which will limit the resistive reach as well as the reactive reach of the Mho characteristic. The positive resistive blinder is built by a line which crosses the R-axis at PDIS.PsRisRch. Please note that it is entered as additional line resistance.

PDIS.PsRisRch

Name: PDIS.PsRisRch
Type: float
Values: 0..999 [ohm prim]

The slope of the resistive blinder is set with the setting via PsRisAng.

PDIS.PsRisAng

PsRisAng is measured counter-clockwise from the R-axis. The area to the right of the blinder is excluded from the operating area.

Name: PDIS.PsRisAng
Type: float
Values: 0..180 [degree]

The negative resistive blinder is built by a line which crosses the R-axis at NgRisRch. Please note that it is entered as additional line resistance.

PDIS.NgRisRch

Name: PDIS.NgRisRch
Type: float
Values: 0..999 [ohm prim]

The slope of the resistive blinder is set with the setting via NgRisAng. NgRisAng is measured counter-clockwise from the R-axis. The area left from the blinder is excluded from the operating area.

PDIS.NgRisAng

Name: PDIS.NgRisAng
Type: float
Values: 0..180 [degree]

The reactive reach blinder is built by a line which crosses the X-axis at PsReactRch.

PDIS. PsReactRch

Name: PDIS. PsReactRch
Type: float
Values: 0..999 [ohm prim]

The slope of the reactive blinder is set with the setting via PsReactAng. PsReactAng is measured counter-clockwise from the horizontal. The area above from the blinder is excluded from the operating area.

PDIS. PsReactAng

Name: PDIS. PsReactAng
Type: float
Values: 0..180 [degree]

4.10 Polygon

The polygon is a characteristic that is used in many multifunctional transmission line protection relays. It can have a different shape depending on the basic shape, number of lines used and the settings of the relay.

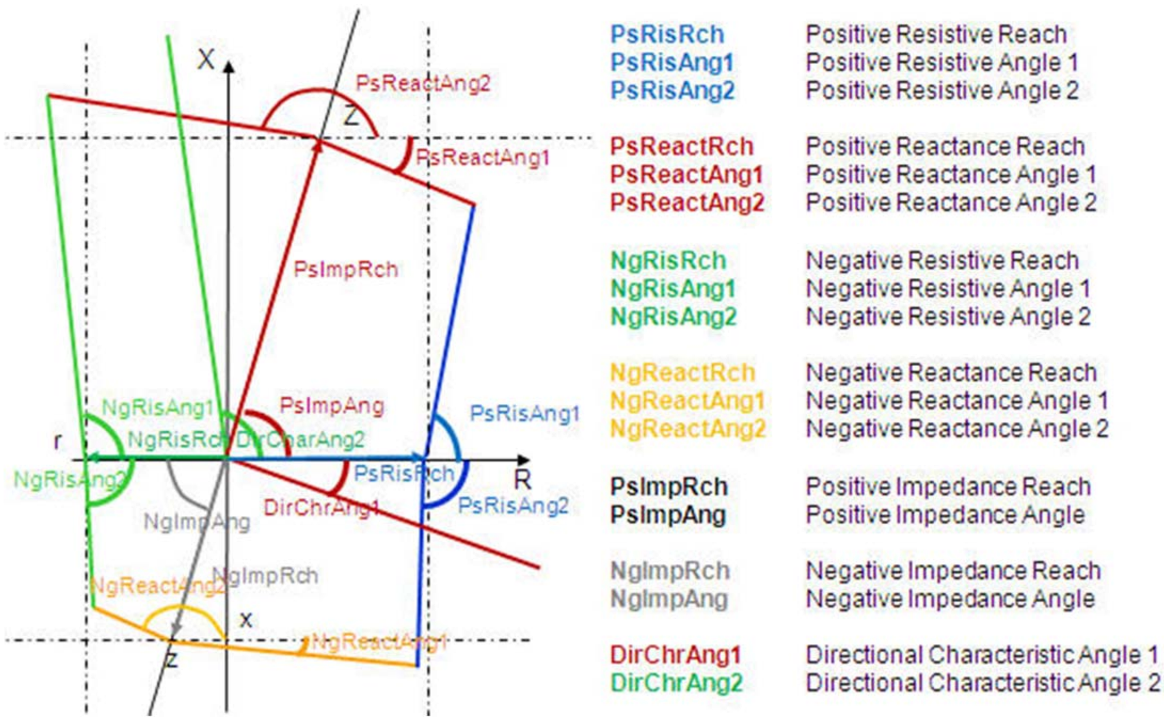


Figure 4.4 Polygon

The characteristic described in this appendix is an abstract characteristic that can be used to represent most existing polygon characteristics using a subset of the characteristic elements defined.

PDIS. PsRisRch

Positive Resistive Reach – defines the positive resistive reach to limit the coverage for fault resistance and at the same time to limit the encroachment of the load impedance into the characteristic. The setting determines the reach on the R axis.

Name: PDIS. PsRisRch
Type: float
Values: 0..999 [ohm prim]

PDIS. PsRisAng1

Positive Resistive Angle in the first quadrant. This angle is measured counter-clockwise from the R-axis. The area right from the blinder is excluded from the operating area.

Name: PDIS. PsRisAng1
Type: float
Values: 0..180 [degree]

PDIS. PsRisAng2

Positive Resistive Angle in the fourth quadrant. This angle is measured clockwise from the R-axis.

Name: PDIS. PsRisAng2
Type: float
Values: 0..180 [degree]

PDIS. PsReactRch

Positive Reactance Reach - defines the positive reactive reach to limit the coverage for fault reactance. The setting determines the reach on the X axis.

Name: PDIS. PsReactRch
Type: float
Values: 0..999 [ohm prim]

PDIS. PsReactAng1

Positive Reactance Angle 1 to the right of the line impedance. This angle is measured clockwise from the horizontal line going through the reactive reach on the X-axis. The area above the line is excluded from the operating area.

Name: PDIS. PsReactAng1
Type: float
Values: 0..180 [degree]

PDIS. PsReactAng2

Positive Reactance Angle 2 to the left of the line impedance. This angle is measured counter-clockwise from the horizontal line going through the reactive reach on the X-axis. The area above the line is excluded from the operating area.

Name: PDIS. PsReactAng2
Type: float
Values: 0..180 [degree]

PDIS. NgRisRch

Negative Resistive Reach – defines the negative resistive reach. The setting determines the reach on the R axis.

Name: PDIS. NgRisRch
Type: float
Values: 0..999 [ohm prim]

PDIS. NgRisAng1

Negative Resistive Angle 1 in the second quadrant. This angle is measured counter-clockwise from the R-axis. The area left from the blinder is excluded from the operating area.

Name: PDIS. NgRisAng1
Type: float
Values: 0..180 [degree]

PDIS. NgRisAng2

Negative Resistive Angle 2 in the third quadrant. This angle is measured counter-clockwise from the R-axis. The area left from the blinder is excluded from the operating area.

Name: PDIS. NgRisAng2
Type: float
Values: 0..180 [degree]

PDIS. NgReactRch

Negative Reactance Reach – defines the reactance reach in the reverse direction.

Name: PDIS. NgReactRch
Type: float
Values: 0..999 [ohm prim]

PDIS. NgReactAng1

Negative Reactance Angle 1. This angle is measured clockwise from the horizontal line going through the negative reactance reach on the X axis. The area below the line is excluded from the operating area.

Name: PDIS. NgReactAng1
Type: float
Values: 0..180 [degree]

PDIS. NgReactAng2

Negative Reactance Angle 2. This angle is measured clockwise from the horizontal line going through the negative reactance reach on the X axis. The area below the line is excluded from the operating area.

Name: PDIS. NgReactAng2
Type: float
Values: 0..180 [degree]

PDIS. PsImpAng

Positive Characteristic Angle – this is the line impedance angle in the forward direction (first quadrant). This angle is measured counter-clockwise from the positive R-axis.

Name: PDIS.PsImpAng
Type: float
Values: 0..180 [degree]

PDIS. NgImpAng

Negative Characteristic Angle – this is the impedance angle in the reverse direction (third quadrant). This angle is measured counter-clockwise from the positive R-axis.

Name: PDIS.NgImpAng
Type: float
Values: 0..180 [degree]

PDIS. DirChrAng1

Directional Characteristic Angle 1 – this is the directional characteristic angle in the fourth quadrant. This angle is measured counter-clockwise from the positive R-axis.

Name: PDIS.DirChrAng1
Type: float
Values: 0..180 [degree]

PDIS. DirChrAng2

Directional Characteristic Angle 2 – this is the directional characteristic angle in the second quadrant. This angle is measured counter-clockwise from the positive R-axis.

Name: PDIS.DirChrAng2
Type: float
Values: 0..180 [degree]

Examples

The following are examples of the use of the models described above:

Non-directional circular characteristic (Ohm)

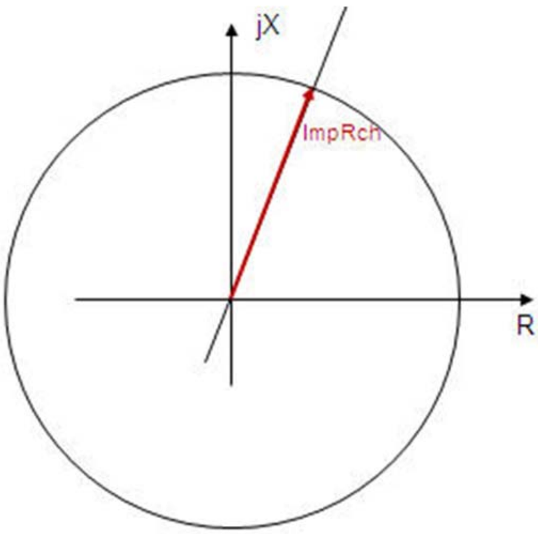
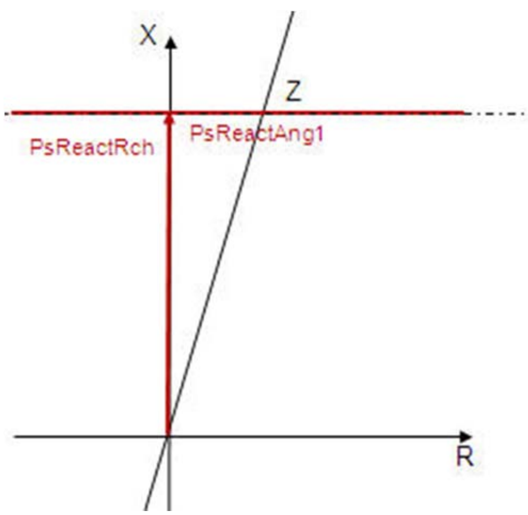


Figure 4.5 ImpRch is the setting of the distance element.

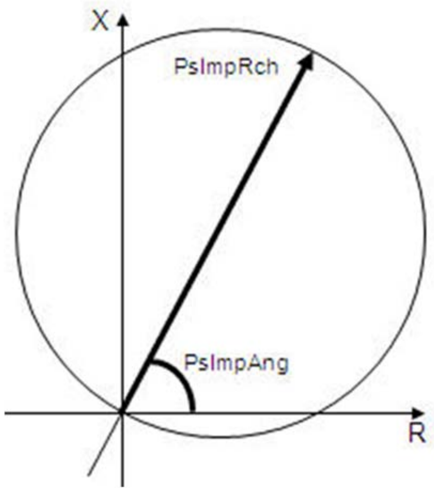
Reactive reach line characteristic



PsReactRch is the positive reactance reach setting of the relay.

PsReactAng1 in the case of a horizontal line will be zero.

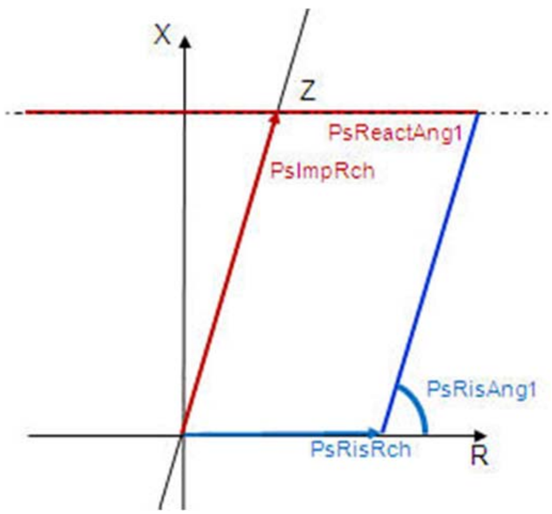
Mho Characteristic



PsImpRch is the impedance reach setting of the distance element.

PsImpAng is the characteristic angle.

Resistive and reactive intersecting lines characteristic



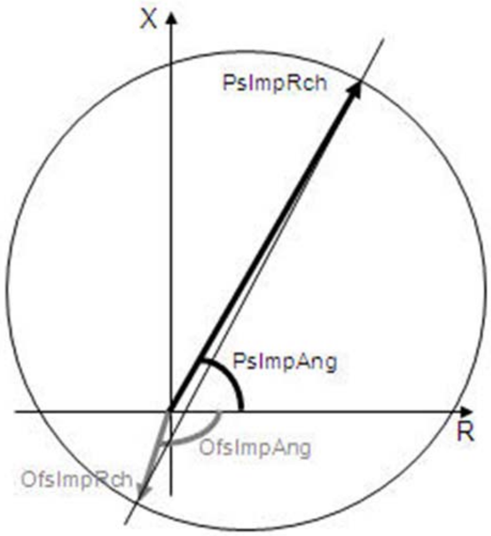
PsImpRch is the positive impedance reach setting of the relay.

PsReactAng1 in the case of a horizontal line will be zero.

PsRisRch is the resistive reach setting of the relay.

PsRisAng1 is the angle of the positive resistive blinder.

Offset Mho



PsImpRch is the impedance reach setting of the distance element.

PsImpAng is the characteristic angle.

OfsImpRch is the offset impedance reach setting of the distance element.

OfsImpAng is the offset characteristic angle.

4.11 Direction

Distance protection functions normally have a directional determination strategy which is independent from the impedance calculation, and is not necessarily based on a calculation using the fault voltages and currents. Under certain conditions, the comparison of healthy phase voltages (cross polarization) or memorized voltages (memory polarization) in relation to the fault current is required.

In many relays the polarization method is fixed. On other relays the polarization method is dynamically selected based on certain conditions. The standard parameter set cannot describe this internal selection logic. However, the settings needed to set the polarization method(s) can be described here.

PDIS. DirMth

Directional Method – defines which polarization method is used or the sequence in which the algorithm would try to use one of the polarization methods.

Name: PDIS.DirMth
Type: enumerated list
Values: Selfpolarized/
Crosspolarized/
Memorypolarized/
Self before Cross before Memory/
Self before Memory before Cross/
Memory before Cross before Self/
Memory before Self before Cross/
Cross before Self before Memory/
Cross before Memory before Self
Self + %Memory
Self+ %Cross
Self+ %Memory +%Cross

Elements used in other functions and defined outside of this report
Superimposed
Power flow
Transient Impedance
Transient Energy
Vo/Io
V2/I2
Vo/I0+V2
Io/Iy
Zero sequence Power
Zo/Z2 evaluation

PDIS. MemVPct

The setting PDIS.MemVPct sets the percentage of the memorized voltage to be used if a polarization method is applied using percent of the memorized voltage.

Name: PDIS.MemVPct
Type: float
Values: 0..100 [%]

PDIS. DirMemoryMin

The setting PDISMemoryMin determines the minimum amplitude of the stored voltage before it is released for use.

Name: PDIS.MemoryMin
Type: float
Values: 0..100 [%]

PDIS. DirCrossPct

The setting PDIS.DirCrossPct sets the percentage of the memorized voltage to be used if a polarization method is applied using percent of the memorized voltage.

Name: PDIS.DirCrossPct
Type: float
Values: 0..100 [%]

PDIS. DirCrossMin

The setting PDIS.DirCrossMin determines the minimum amplitude of the healthy phase's voltage before it is released for use.

Name: PDIS.CrossMin
Type: float
Values: 0..100 [%]

PDIS. DirSelfMin

The setting PDISDirSelfMin determines the minimum amplitude of the faulted voltage before it is released for use.

Name: PDIS.DirSelfMin
Type: float
Values: 0..100 [%]

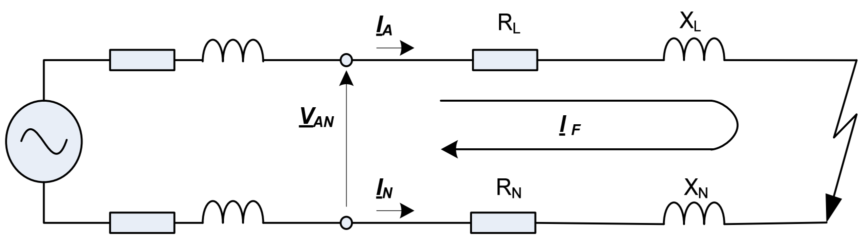
PDIS. DirMemoryLenV

The setting PDISMemoryLength sets the length of the memory voltage buffer.

Name: PDIS.MemoryLength
Type: float
Values: 0..999 [cycle]

4.12 Residual Compensation (only ground elements)

On phase to phase faults the distance function can simply calculate the fault impedance from the relay location to the fault location by dividing the phase-to-phase loop impedance by a factor of 2. On ground faults where the fault current returns via ground, this factor of 2 cannot be applied anymore because the ground impedance share of the loop impedance is different from the line impedance part. Most manufacturers use a residual compensation factor to describe the relationship between the ground impedance $\underline{Z}_N$ and line impedance $\underline{Z}_L$ and use this factor to calculate the line portion of the loop impedance.



with $\underline{k}_N = \frac{\underline{Z}_N}{\underline{Z}_L}$

$$\underline{Z}_{Loop} = \frac{\underline{V}_{AN}}{\underline{I}_F} = \underline{Z}_L + \underline{k}_N \underline{Z}_L = (1 + \underline{k}_N)\underline{Z}_L$$

$$\underline{Z}_L = \frac{\underline{V}_{AN}}{\underline{I}_F(1 + \underline{k}_N)}$$

When setting the distance zone, most manufacturers express the ground return impedance in terms of the positive-sequence reach by multiplying it with the residual compensation factor, but other manufacturers use a different form of multiplier. Therefore, for a common data exchange the positive- and zero-sequence impedance settings of the impedance zone will be used and the residual compensation method that the manufacturer uses will be indicated.

The common format for ground impedance zone basic reach settings consists of:

Z1 – the positive-sequence line impedance polar reach of the zone, consisting of

PDIS.ZPsMag

The PDIS.ZPsMag is the modulus of Z1, the positive-sequence zone polar reach

Name: PDIS.ZPsMag
Type: float
Values: 0..999 [ohm prim]

PDIS.ZPsAng

The PDIS.ZPsAng is the angle or argument of Z1, the positive-sequence zone polar reach

Name: PDIS.ZPsAng
Type: float
Values: 0..90 [degree]

Z0 – the zero-sequence impedance polar reach of the zone, consisting of

PDIS.ZZerMag

The PDIS.ZzerMag is the modulus of Z0, the zero-sequence zone polar reach

Name: PDIS.ZZerMag
Type: float
Values: 0..999 [ohm prim]

PDIS.ZZerAng

The PDIS.ZZerAng is the angle or argument of Z0, the zero-sequence zone polar reach

Name: PDIS.ZZerAng
Type: float
Values: 0..90 [degree]

For clarification the relation between ground and zero-sequence impedance is mentioned as $\underline{Z}0=\underline{Z}1+1/3*\underline{Z}N$.

PDIS. ResCMth

PDIS.ResCMth – the method of residual compensation used internally by the relay. This setting is needed in order to correctly model the loop impedance characteristic of the zone, especially for polygon characteristics.

From the zone Z1 and Z0 settings the residual compensation can be calculated regardless of the method that the relay uses. Most relays do not have a setting for zero-sequence impedance, Z0, but do have a setting for residual compensation and positive-sequence impedance reach, Z1. For data exchange, the value of Z0 needs to be calculated.

Name: PDIS. ResCMth
Type: enumerated list
Values: ZN /KN/ RERL_XEXL/ K01/K02/ R0R1_X0X1

ZN:
ZN is the earth-return impedance and it consists of
ZNmag – the modulus of ZN, and

ZNang– the angle of ZN

KN:
Residual compensation factor, KN, is a complex number that is used to express the earth-return impedance, ZN, in terms of the positive-sequence impedance reach setting, Z1. This factor is calculated as:

KN = ZN / Z1 = (Z0 – Z1) / (3Z1)

It consists of:
KNmag – modulus of KN
KNang – angle of KN

RERL_XEXL:
The pair of scalar factors RE/RL and XE/XL affects the resistive reach and reactive reach, respectively, of some polygon characteristics. They are calculated as follows:

RERL = (R0/R1 – 1)/3
XEXL = (X0/X1 – 1)/3

Where:
R1 = real part of Z1
X1 = imaginary part of Z1
R0 = real part of Z0
X0 = imaginary part of Z0

K0 1:
Zero-sequence current compensation factor, K0, is a complex number and is used by the relay in a similar manner to KN.

K0 = (Z0 – Z1) / Z1

It consists of:
K0mag – modulus of K0
K0ang – angle of K0

K0 2 or Z0Z1 Ratio – is the complex ratio of Z0/Z1

K0=Z0/Z1:
It consists of:
K0mag – modulus of K0
K0ang – angle of K0

R0R1_X0X1 - consists of a pair of scalar factors R0/R1 and X0/X1.

Parallel Line Mutual Compensation

The parallel line mutual compensation factor compensates the earth-fault impedance measurement due to earth or residual current flowing on the parallel line and mutual impedance between the lines. For data exchange the following settings are used.

PDIS.Z1P – the positive-sequence polar line impedance of the section which is parallel to the mutual coupled line. If only a part of the line is in parallel with another line, Z1P can be different from the positive-sequence impedance reach setting of the zone Z1. PDIS.Z1P consists of

ZLIN.ZPsZmMag

The ZLIN.ZPZmMag is the modulus of Z1, the positive-sequence line impedance which is mutually-coupled with a parallel line. ZLIN.ZPsZmMag can be different from ZLIN.ZPsMag if only a part of the line is in parallel with another line.

Name: ZLIN.ZmZerMag
Type: float
Values: 0..999 [Ohm prim]

*ZLIN.ZPsZm*Ang

The ZLIN.ZPsZmAng is the angle or argument of Z1, the positive-sequence line impedance which is mutually-coupled with a parallel line.

Name: ZLIN.ZPsZmAng
Type: float
Values: 0..90 [degree]

Z0M– is the zero-sequence mutual impedance between the protected line and the parallel line

*ZLIN.ZmZer*Mag

The ZLIN.ZmZerMag is the modulus of Z0, the zero-sequence mutual impedance.

Name: ZLIN.ZmZerMag
Type: float
Values: 0..999 [Ohm prim]

*ZLIN.ZmZer*Ang

The ZLIN.ZmZerAng is the angle or argument of Z0, the zero-sequence mutual impedance.

Name: ZLIN.ZmZerAng
Type: float
Values: 0..90 [degree]

PDIS.ZmZerCMth

PDIS.ZmZerCMth– the method of parallel line mutual compensation used internally by the relay.

Name: PDIS.ZmZerCMth
Type: enumerated list
Values: K0m1/K0m2/ RmRL_XmXL / RmR1_XmX1

From the Z1 and Z0m settings the zero-sequence mutual compensation can be calculated regardless of the method that the relay uses. Most relays do not have a setting for zero-sequence mutual impedance, Z0m, but do have a setting for mutual compensation and positive-sequence impedance, Z1. In this case, for data exchange the value of Z0m needs to be calculated.

Some of the common methods of zero-sequence mutual compensation are listed below. In all cases Z1 is known.

K0m method 1
K0m, is a complex number that is used to express the zero-sequence mutual impedance, Z0M, in terms of the positive-sequence impedance. This factor is calculated as:

K0m = Z0m / 3Z1

The mutual compensation factor, K0m, is set with two parameters:

K0mMod – is the modulus of K0m; it is unitless
K0mAng – is the angle or argument of K0m in degrees

K0m method 2
Note that in some relays the K0M is defined as the complex ratio Z0m/Z1.
K0mMod – is the modulus of K0m; it is unitless
K0mAng – is the angle or argument of K0m in degrees

RmRL_XmXL method

It consists of a pair of scalar factors RM/RL and XM/XL. These factors affect the resistive reach and reactive reach, respectively, of some polygon characteristics. They are calculated as follows:

RmRL = (R0m/R1 – 1)/3
XmXL = (X0m/X1 – 1)/3

Where:
R1 = real part of Z1
X1 = imaginary part of Z1
R0m = real part of Z0m

X0m = imaginary part of Z0m

RmR1_XmX1
This uses the simple ratios as defined below.
RmR1 = R0m/R1
XmX1 = X0m/X1

PDIS.ResAmRat

The PDIS.ResAmRat setting determines the ratio of the residual current from the parallel line to the residual current of the protected line above which the mutual compensation calculation will be blocked.

Name:	PDIS.ResAmRat
Type:	float
Values:	0..200 [%]

5 Common Format Definition

5.1 Introduction

By attempting to define a common format for settings, this report distinguishes the two following aspects:

- The semantic definition, i.e. the unambiguous meaning of a setting, typically by using a name, a description and a data type. These attributes should be part of a name space definition.
- The physical format used to exchange the information between applications.

Important note: It is worth noting an additional aspect. Protection settings are often stored in a database (mainly a relational database). The internal format of the database is outside the scope of this report.

5.2 Basic format

5.2.1 Semantic definitions

The preceding clauses of this report make recommendations to extend the data model format defined in the IEC 61850 standard. More specifically, they define new data objects that are intended to be added in the IEC 61850-7-4 name space. As for the common data classes (CDC in IEC 61850-7-3) that define the data object types, no need for new CDCs has been identified so far. Most of the new data object types refer to the CDCs specifications related to settings. They are mainly the following:

- SPG, Single point setting, value = BOOLEAN;
- ENG, Enumerated status setting, value = ENUMERATED;
- ASG, Analogue setting, value = Analogue Value.

5.2.2 Exchange format specification

This report recommends use of the XML format specified in IEC 61850-6 as the basic format for exchanging relay settings and their values between applications. IEC 61850-6 details an XML schema based on the W3C recommendations[1].

Section 5.3.3 shows a possible XML instance file based on the IEC 61850-6 format. It contains the new data PsRisRch (Positive Resistive Reach) defined in this report. The attributes setMag and units have respectively the value 75 and ohms.

[1] World Wide Web (W3) Consortium publications are available from the World Wide Web Consortium, Massachusetts Institute of Technology, 32 Vassar Street, Room 32-G515, Cambridge, MA 02139 (http://www.w3.org/).
http://www.w3.org/TR/2004/REC-xmlschema-1-20041028/structures.html.
http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/datatypes.html.
http://www.w3.org/TR/2004/REC-xml-names11-20040204/.

5.3 Extensions to the Format (Private Settings)

It is not the purpose of this report to define 100% of the configuration data for protection settings. However, the working group believes that if 80% or more of the settings could be standardized, this would be very beneficial for the different stakeholders.

Thus, an extension mechanism must be provided for allowing the definition of some very specific functions or for taking into account the continuous advancement of the technology. The IEC 61850 standard already makes this mechanism available and the common rules for extending object classes is specified in IEC 61850-7-1. The two rules of interest for this report are defined in the following clauses.

5.3.1 Extending a function by adding new data object class

In IEC 61850, functions are defined by means of logical nodes, e.g. PDIS. New data object classes may be defined by a third party in such functions with the condition not to change the semantics of the function (e.g. PDIS is and must stay a distance protection function). Moreover, the new data object class shall be marked by a name space identification different from the owner's name space identification, i.e. different from IEC 61850 in our case.

In the example shown in section 5.3.3 the logical node PDIS has been extended with a new data class named MynewdataclassPct. This is a private extension whose name space name is indicated by the attribute dataNs and the value MyOnwNamespaceName:2011A. The latter indicates where to find the actual meaning of MynewdataclassPct; it may be a document or a URL. In addition, the abbreviation Pct in the data name indicates that the value is in percent, thus following the rules given in IEC 61850-7-1.

5.3.2 Extending a function by making new versions of common data classes or by adding new common data classes

In IEC 61850, common data classes specify the data type (e.g. ASG, Analogue Setting). IEC 61850-7-1 only allows new versions of common data classes or definitions of new common data classes to be specified by the owner of the name space, i.e. the IEC TC 57 entity. It means that a third party cannot define such new items. This is required for interoperability issues as these settings are not only intended to be exchanged off line (this is what this report aims at) but also on line. As already mentioned, the working group has not yet identified the need for new common data classes as far as the line distance protection function is concerned.

5.3.3 Example of an instance file

```xml
<?xml version="1.0" encoding="UTF-8"?>
<SCL>
	<!--......-->
	<LN lnType="PDIS1" lnClass="PDIS" inst="1" prefix="Z1G">
```

```
<DOI name="Beh">
	<DAI name="stVal"/>
	<DAI name="q"/>
</DOI>
<DOI name="NamPlt">
	<DAI name="vendor">
		<Val>SomeVendor</Val>
	</DAI>
	<DAI name="swRev">
		<Val>swRev number</Val>
	</DAI>
</DOI>
<DOI name="Str">
	<DAI name="general"/>
	<DAI name="dirGeneral"/>
	<DAI name="q"/>
</DOI>
<DOI name="Op">
	<DAI name="general"/>
	<DAI name="q"/>
</DOI>
<DOI name="PsRisRch">
	<DAI name="d">
		<Val>Positive Resistive Reach – defines the positive
resistive reach to limit the coverage for fault resistance and at the same time to limit the
encroachment of the load impedance into the characteristic. The setting determines the
reach on the R axis</Val>
	</DAI>
	<SDI name="setMag">
		<DAI name="f">
			<Val>75</Val>
		</DAI>
	</SDI>
	<SDI name="units">
		<DAI name="unit">
			<Val>30</Val>
		</DAI>
		<DAI name="multiplier">
			<Val>0</Val>
		</DAI>
	</SDI>
</DOI>
<DOI name="MynewdataclassPct">
	<SDI name="setMag">
		<DAI name="f">
			<Val>1.1</Val>
		</DAI>
	</SDI>
	<SDI name="units">
```

```xml
                        <DAI name="unit">
                            <Val>1</Val>
                        </DAI>
                        <DAI name="multiplier">
                            <Val>-2</Val>
                            <DAI name="d">
                                <Val>this is an example of a private
extension: the name of the data ends with Pct (ref. IEC 61850-7-4) meaning that the
value of the setting is in percent</Val>
                            </DAI>
                        </DAI>
                        <DAI name="dataNs">
                            <Val>MyOnwNamespaceName:2011A</Val>
                        </DAI>
                    </SDI>
                </DOI>
            </LN>
            <!--.. ...-->
            <DataTypeTemplates>
                <LNodeType id="PDIS1" lnClass="PDIS" iedType="XX_21">
                    <DO name="Mod" type="modINC"/>
                    <DO name="Beh" type="behINS"/>
                    <DO name="Health" type="healthINS"/>
                    <DO name="NamPlt" type="LPL_0"/>
                    <DO name="Str" type="ACD_0"/>
                    <DO name="Op" type="ACT_0"/>
                    <DO name="PsRisRch" type="ASG_0"/>
                    <DO name="MynewdataclassPct" type="ASG_0"/>
                </LNodeType>
                <!--.. ...-->
                <DOType id="ASG_0" cdc="ASG">
                    <DA name="setMag" fc="SE" bType="Struct"
type="AnalogValue_0"/>
                    <DA name="units" fc="CF" bType="Struct" type="Units_0"/>
                </DOType>
                <!--.. ...-->
                <DAType id="Units_0">
                    <BDA name="unit" bType="Enum" type="SIUnit"/>
                    <BDA name="multiplier" bType="Enum" type="multiplier"/>
                </DAType>
                <!--.. ...-->
                <EnumType id="SIUnit">
                    <EnumVal ord="1">none</EnumVal>
                    <EnumVal ord="2">m</EnumVal>
                    <EnumVal ord="3">kg</EnumVal>
                    <EnumVal ord="4">s</EnumVal>
                    <EnumVal ord="5">A</EnumVal>
                    <EnumVal ord="6">K</EnumVal>
                    <EnumVal ord="7">mol</EnumVal>
```

```
<EnumVal ord="8">cd</EnumVal>
<EnumVal ord="9">deg</EnumVal>
<EnumVal ord="10">rad</EnumVal>
<EnumVal ord="11">sr</EnumVal>
<EnumVal ord="21">Gy</EnumVal>
<EnumVal ord="22">q</EnumVal>
<EnumVal ord="23">°C</EnumVal>
<EnumVal ord="24">Sv</EnumVal>
<EnumVal ord="25">F</EnumVal>
<EnumVal ord="26">C</EnumVal>
<EnumVal ord="27">S</EnumVal>
<EnumVal ord="28">H</EnumVal>
<EnumVal ord="29">V</EnumVal>
<EnumVal ord="30">ohm</EnumVal>
<EnumVal ord="31">J</EnumVal>
<EnumVal ord="32">N</EnumVal>
<EnumVal ord="33">Hz</EnumVal>
<EnumVal ord="34">lx</EnumVal>
<EnumVal ord="35">Lm</EnumVal>
<EnumVal ord="36">Wb</EnumVal>
<EnumVal ord="37">T</EnumVal>
<EnumVal ord="38">W</EnumVal>
<EnumVal ord="39">Pa</EnumVal>
<EnumVal ord="41">m²</EnumVal>
<EnumVal ord="42">m³</EnumVal>
<EnumVal ord="43">m/s</EnumVal>
<EnumVal ord="44">m/s²</EnumVal>
<EnumVal ord="45">m³/s</EnumVal>
<EnumVal ord="46">m/m³</EnumVal>
<EnumVal ord="47">M</EnumVal>
<EnumVal ord="48">kg/m³</EnumVal>
<EnumVal ord="49">m²/s</EnumVal>
<EnumVal ord="50">W/m K</EnumVal>
<EnumVal ord="51">J/K</EnumVal>
<EnumVal ord="52">ppm</EnumVal>
<EnumVal ord="53">1/s</EnumVal>
<EnumVal ord="54">rad/s</EnumVal>
<EnumVal ord="61">VA</EnumVal>
<EnumVal ord="62">Watts</EnumVal>
<EnumVal ord="63">VAr</EnumVal>
<EnumVal ord="64">theta</EnumVal>
<EnumVal ord="65">Cos (theta)</EnumVal>
<EnumVal ord="66">Vs</EnumVal>
<EnumVal ord="67">V²</EnumVal>
<EnumVal ord="68">As</EnumVal>
<EnumVal ord="69">A²</EnumVal>
<EnumVal ord="70">A²t</EnumVal>
<EnumVal ord="71">VAh</EnumVal>
<EnumVal ord="72">Wh</EnumVal>
```

```xml
				<EnumVal ord="73">VArh</EnumVal>
				<EnumVal ord="74">V/Hz</EnumVal>
			</EnumType>
			<EnumType id="multiplier">
				<EnumVal ord="-24">y</EnumVal>
				<EnumVal ord="-21">z</EnumVal>
				<EnumVal ord="-18">a</EnumVal>
				<EnumVal ord="-15">f</EnumVal>
				<EnumVal ord="-12">p</EnumVal>
				<EnumVal ord="-9">n</EnumVal>
				<EnumVal ord="-6">μ</EnumVal>
				<EnumVal ord="-3">m</EnumVal>
				<EnumVal ord="-2">c</EnumVal>
				<EnumVal ord="-1">d</EnumVal>
				<EnumVal ord="0"/>
				<EnumVal ord="1">da</EnumVal>
				<EnumVal ord="2">h</EnumVal>
				<EnumVal ord="3">k</EnumVal>
				<EnumVal ord="6">M</EnumVal>
				<EnumVal ord="9">G</EnumVal>
				<EnumVal ord="12">T</EnumVal>
				<EnumVal ord="15">P</EnumVal>
				<EnumVal ord="18">E</EnumVal>
				<EnumVal ord="21">Z</EnumVal>
				<EnumVal ord="24">Y</EnumVal>
			</EnumType>
			<!--.. ...-->
		</DataTypeTemplates>
</SCL>
```

Reference

Instruction manual

[M1] Technical Reference Manual, “Line Distance Protection IED REL670”, ABB, Document No: 1MRK 506 275-UUS, March 2007

[M2] Service Manual, “LFZR”, Alstom, LFZR/EN M/F11, Aug 2003

[M3] Technical Manual, “MiCom P441, P442, P444”, Alstom, P44x/EN M/H85, 2011

[M4] Instruction Manual, “D30 Line Distance Protection System”, GE Multilin, Manual P/N 1601-0116-X1 (GEK-113599), 2011

[M5] Instruction Manual, “D60 Line Distance Protection System”, GE Multilin, Manual P/N 1601-0089-X1 (GEK-113589), 2011

[M6] Instruction Manual, “SEL-421-4,-5 Relay”, SEL, Data Code 20110628, 2011

[M7] Instruction Manual, “SIPROTEC 7SA510 V3.2”, Siemens, Order No. C53000-G1176-C115-3, 1997

[M8] Instruction Manual, “SIPROTEC 7SA511 V3.2”, Siemens, Order No. C53000-G1176-C98-6, 1995

[M9] Instruction Manual, “SIPROTEC 7SA513 V3.2/V3.3”, Siemens, Order No. C53000-G1176-C103-6, 1995

[M10] Instruction Manual, “Numerical Overhead Contact-Line Protection 7SA518/7SA519 V3.2”, Siemens, Order No. C53000-G1176-C108-3, 1999

[M11] Instruction Manual, “SIPROTEC Distance Protection 7SA522 V4.3”, Siemens, Order No. C53000-G1140-C155-3, 2004

[M12] Instruction Manual, “Distance Relay GRZ100-***B”, Toshiba, No. 6F2S0846, 2006

Standards

[S1] IEC61850-7-4 Ed.2 “Basic communication structure – Compatible logical node classes and data object classes”, IEC, 2009

Appendix

Phase selection using fault inception detectors

There are two common approaches for identifying fault inception transients used for high speed faulted phase selection. The first is a fault transient filtering method (a.k.a. traveling wave) and is based on a high-speed process that passes the transient component of system voltage and current changes (fault inception, breaker operations, etc.) by filtering out fundamental frequency steady-state pre-fault and fault components. The measured transient peak, DX, exceeding a threshold value indicates the faulted phase X. A second method is based on high-speed sampled data change detectors (a.k.a. superimposed components) that measure the difference in the most current sampled value of voltage or current, ST, with the respective phase aligned sampled value measured k cycles earlier. The measured change is DX = |ST - ST-kN|, where N is the number of samples per cycle and k is an integer multiple of cycles usually 1 or 2. The measured change, DX, exceeding a threshold value indicates the faulted phase X. Figure 1 illustrates the phase selection process using the delta pulse generated by either fault inception detection method.

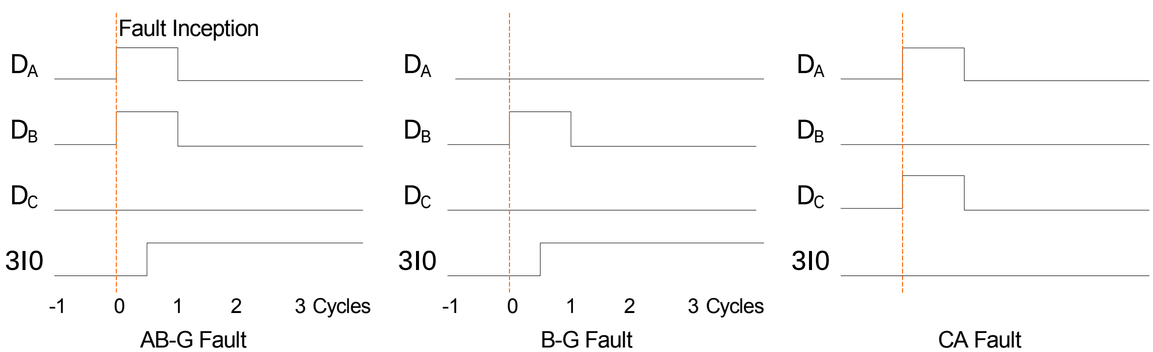


Figure 1. Delta method for high-speed faulted phase selection

Using either fault transient detection method, accurate high-speed faulted phase determination is made simply by measuring the voltage and/or current changes that occur on each phase and ground (zero sequence). Since these methods are based on the fault transients, they can provide high-speed faulted phase selection but generally need to be complemented with other methods of faulted phase selection for faults requiring longer clearing times.

Parameter settings for phase selection with fault inception detectors

Parameter	Description
DeltaIMinOp	The minimum output of the current change detector in %IBase used for the delta phase selection method
DeltaVMinOp	The minimum output of the voltage change detector in % Vbase/√3 used for the delta phase selection method

Phase selection using symmetrical component quantities

The symmetrical component method uses phase A sequence quantities to determine the correct faulted phases. It accurately calculates and sustains the phase selection information until the fault is cleared. Phase selection is achieved by evaluating the angle of V_{A2}/I_{A0} and/or V_{A2}/V_{A1}.

The absence of appreciable negative and zero sequence quantities indicates a three-phase fault condition. Also, having substantial negative sequence and no appreciable zero sequence quantities defines a phase-to-phase fault. If a phase-to-phase fault is identified then involved phases are identified by a phase-to-phase selector

Parameter settings for phase selection with symmetrical components

Parameter	Description
V1Level	The positive sequence voltage level in % Vbase/√3 below which a three-phase fault can be identified using the symmetrical component method
I1LowLevel	The minimum positive sequence current level in % Ibase for which a three-phase fault can be identified using the symmetrical component method
V1MinOp	The minimum positive sequence voltage level in % Vbase/√3 that allows phase selection operation with symmetrical components
V2MinOp	The minimum negative sequence voltage level in % Vbase/√3 that allows phase selection operation with symmetrical components
INRelPE	The level of 3I0 required to release the phase-to-ground loops of the distance units. The setting should be greater than the 3I0 that occurs with an open phase and at least 10% less than the 3I0BLK_PP setting.
3I0BLK_PP	The level of 3I0 that blocks phase-to-phase loops.

Phase selection using distance measurement characteristics

Phase selection may also be achieved using distance measuring characteristics, either mho or quadrilateral, for the six fault loops, AG, BG, CG, AB, BC and CA. The operation of these impedance measuring loops along with zero sequence current and fault direction measurement are used to determine the faulted phases. The settings parameter requirements are generally the same as that for a similar distance measurement zone characteristic. In addition, the settings INRelPE and 3I0BLK_PP noted in the above table (symmetrical components) may also be required.

Phase selection using only current quantities

For current differential or other current only systems where voltage measurement is not available the phase current magnitudes may be used for faulted phase identification. A common method is to use sequence quantities along with comparing the magnitude differences of the phase quantities measured during the fault.

Parameter settings for phase selection with only current quantities

Parameter	Description
I1MinOp	The minimum positive sequence current level in % Ibase that defines the presence of I1
I2MinOp	The minimum negative sequence current level in % Ibase that defines the presence of I2
I0MinOp	The minimum zero sequence current level in % Ibase that defines the presence of I0