SILENT
DIG

PowerFactory 2021

Technical Reference

ABB REF 542+

PF2021

Contents

1   Model information

Manufacturer   ABB

Model   REF 542+

Variants   The ABB REF 542+ PowerFactory relay model can be used to simulate the ABB REF 543 relay.

2   General description

The ABB REF 542+ PowerFactory relay model consists of a main relay model and the following sub relays:

- REF 542+ overcurrent
- REF 542+ voltage elements (F27-F59)
- REF 542+ frequency (F81)
- REF 542+ distance (F21)
- REF 542+ differential (F87)

The ABB REF 542+ PowerFactory relay model has been implemented trying to simulate the protective functions more commonly used.

The main relay contains the measurement and acquisition units, the output logic and all other sub relays.

The model implementation has been based on the information available in the relay manual [1].

3   Supported features

3.1   Measurement and acquisition

The voltage and the current are measured by two current transformers ("Ct" and "Neutral Ct" blocks) and one voltage transformer ("Vt" block). Two additional current transformers are used by the differential element: the "Remote Ct" and the "Remote Neutral Ct" block represent the CTs located at the other line terminals.

Six measurement units ("Measurement", "Mea Idelta" , "Measurement Seq", "Meas Neutral I", "Remote Measurement", "Remote Neutral Measurement" block) are fed by these CTs and the VT.

3.1.1   Available Units

- Ct (provides the current instantaneous values at the relay position)

- Neutral Ct (provides the current flowing in the neutral at the relay position)

- Vt (provides the voltage instantaneous values at the relay position)

- Remote Ct

- Remote Neutral Ct

- Measurement

- Mea Idelta

- Measurement Seq

- Meas Neutral I (fed by the *Neutral Ct*)

- Remote Measurement (fed by the *Remote Ct*)

- Remote Neutral Measurement (fed by the *Remote Neutral Ct*)

3.1.2   Functionality

The input signals are sampled at 20 samples/cycle; a DFT filter operating over a cycle calculates then the voltage and current values used by the protective elements.

3.1.3   Data input

The nominal current and the nominal voltage values MUST be entered in all the measurement units.

3.2   REF 542+ overcurrent subrelay

The ABB REF 542+ relay offers a quite large choice of overcurrent protection functions. The PowerFactory ABB REF 542+ relay model implements the most commonly used functions.

3.2.1   Available Units

- two directional time defined phase overcurrent elements *Dir I>, DIR I>>* ("I> ->", "I>> ->" block)

- one phase directional element ("Phase Dir" block)

- three time defined phase overcurrent elements ("I>", "I>>", "I>>>" block)

- one IDMT phase overcurrent element *NOC* ("Phase IDMT" block)

- two time defined earth current elements using the measured earth current *EFnd>, EFnd>>* ("EF> meas", "EF>> meas" block)

- two time defined earth current elements using the calculated earth current *EFnd>, EFnd>>* ("EF> calc", "EF>> calc" block)

- two directional time defined earth current elements using the measured earth current ("EF> -> meas", "EF>> -> meas" block)

- one earth directional element using the measured earth current ("Earth Dir Meas" block)

- two directional time defined earth current elements using the calculated earth current ("EF> -> calc", "EF>> -> calc" block)

- one earth directional element using the calculated earth current ("Earth Dir Calc" block)

- one sensitive directional time defined earth current element ("EF> sens")

- one sensitive earth directional element(" Sensitive Earth Dir" block)

- one IDMT earth overcurrent element using the calculated earth current ("Earth IDMT calc" block)

- one IDMT earth overcurrent element using the measured earth current ("Earth IDMT meas" block)

- one reclosing element associated to the phase overcurrent elements ("Ph reclosing" block)

- one reclosing element associated to the earth overcurrent elements ("Earth reclosing" block)

3.2.2   Functionality

The inverse time overcurrent elements support the following trip characteristics:

- Definite time

- Extremely inverse

- Long time inverse

- Very inverse

• Normal inverse

A double set of earth fault overcurrent elements is present: one is fed with the zero sequence current measured by the "Neutral Ct" block , one is fed with the zero sequence current calculated buy the "Ct" block (simulating an Holmgreen's CT connection).

3.2.3   Data input

The relationships between the relay settings and the model parameters can be found in the following table:

Address	Relay Setting	Model block	Model setting	Note
	Dir I>	I> ->	Pickup Current	
	Dir I>	I> ->	Time Setting	
	Dir I>>	I>> ->	Pickup Current	
	Dir I>>	I>> ->	Time Setting	
	NOC Status	Phase IDMT	Out of Service	
	NOC A,P,B	Phase IDMT	Characteristic	Set one of the predefined TCC
	NOC Td	Phase IDMT	Time Dial	
	NOC Reset Type	Phase IDMT	Reset Characteristic	Only the Definite Time reset cna be set
	NOC Reset Time	Phase IDMT	Reset Delay	
	NOC Start Value	Phase IDMT	Current Settings	
	NOC Def.operate Time	Phase IDMT	Time Dial	Set the "Definite Time TCC" characteristic
	I>	I>	Pickup Current	
	I>	I>	Time Setting	
	I>>	I>>	Pickup Current	
	I>>	I>>	Time Setting	
	I>>>	I>>>	Pickup Current	
	I>>>	I>>>	Time Setting	
	EFnd>(connected to "Ct")	EF> calc	Pickup Current	
	EFnd>(connected to "Ct")	EF> calc	Time Setting	
	EFnd>>(connected to "Ct")	EF>> calc	Pickup Current	
	EFnd>>(connected to "Ct")	EF>> calc	Time Setting	
	EFnd>(connected to "Neutral Ct")	EF> meas	Pickup Current	
	EFnd>(connected to "Neutral Ct")	EF> meas	Time Setting	
	EFnd>>(connected to "Neutral Ct")	EF>> meas	Pickup Current	
	EFnd>>(connected to "Neutral Ct")	EF>> meas	Time Setting	
	EF Current Io	EF> sens	Pickup Current	
	EF Time	EF> sens	Time Setting	
	EF Angle Alpha	Sensitive Earth Dir	Angle Operating Sector	Set Angle Operating Sector =90-Alpha
	EF Angle Delta	Sensitive Earth Dir	Max. Torque angle	In the "Voltage polarizing" tab page
	EF Voltage Uo	Sensitive Earth Dir	Polarizing Voltage	In the "Voltage polarizing" tab page
	Earth Fault IDMT Status ("Ct")	Earth IDMT calc	Out of Service	
	Earth Fault IDMT A,P,B ("Ct")	Earth IDMT calc	Characteristic	Set one of the predefined TCC
	Earth Fault IDMT Td ("Ct")	Earth IDMT calc	Time Dial	

Address	Relay Setting	Model block	Model setting	Note
	Earth Fault IDMT Reset Type ("Ct)	Earth IDMT calc	Reset Characteristic	Only the Definite Time reset cna be set
	Earth Fault IDMT Reset Time ("Ct)	Earth IDMT calc	Reset Delay	
	Earth Fault IDMT Start Value ("Ct)	Earth IDMT calc	Current Settings	
	Earth Fault IDMT Def.operate Time ("Ct)	Earth IDMT calc	Time Dial	Set the "Definite Time TCC" characteristic
	Earth Fault IDMT Status ("Neutral Ct")	Earth IDMT meas	Out of Service	
	Earth Fault IDMT A,P,B ("Neutral Ct")	Earth IDMT meas	Characteristic	Set one of the predefined TCC
	Earth Fault IDMT Td ("Neutral Ct")	Earth IDMT meas	Time Dial	
	Earth Fault IDMT Reset Type ("Neutral Ct")	Earth IDMT meas	Reset Characteristic	Only the Definite Time reset cna be set
	Earth Fault IDMT Reset Time ("Neutral Ct")	Earth IDMT meas	Reset Delay	
	Earth Fault IDMT Start Value ("Neutral Ct")	Earth IDMT meas	Current Settings	
	Earth Fault IDMT Def.operate Time ("Neutral Ct")	Earth IDMT meas	Time Dial	Set the "Definite Time TCC" characteristic
	Autoreclose Number of Reclosure cycles	Ph Reclosing	Operations to Lockout	Set equal to "Number of Reclosure cycles"+1
		Earth Reclosing	Operations to Lockout	Set equal to "Number of Reclosure cycles"+1
	Autoreclose Reclaim Time	Ph Reclosing	Reset Time	
		Earth Reclosing	Reset Time	
	Autoreclose Dead Time First Shot	Ph Reclosing	Reclosing Interval 1	
		Earth Reclosing	Reclosing Interval 1	
	Autoreclose Dead Time Second Shot	Ph Reclosing	Reclosing Interval 2	
		Earth Reclosing	Reclosing Interval 2	
	Autoreclose Dead Time Third Shot	Ph Reclosing	Reclosing Interval 3	
		Earth Reclosing	Reclosing Interval 3	
	Autoreclose Dead Time Fourth Shot	Ph Reclosing	Reclosing Interval 4	
		Earth Reclosing	Reclosing Interval 4	
	Autoreclose Dead Time Fifth Shot	Ph Reclosing	Reclosing Interval 5	
		Earth Reclosing	Reclosing Interval 5	
	Autoreclosure Apply autoreclosure function to...	Ph Reclosing	Logic	In the "Logic" tab page
		Earth Reclosing	Logic	In the "Logic" tab page

Please notice that setting the directional earth fault feature elements, when the "Net Type" parameter is set to "earthed", the "Max Torque angle" parameter in the "Earth dir" block must be set equal to 0; when the "Net Type" parameter is set to "isolated" the "Max Torque angle" parameter in the "Earth dir" block must be set equal to -90.

Please notice that setting the directional earth fault feature elements using the measured earth current, in the model the "Angle operating sector" variable is equal to 90°- "Angle alpha" relay setting.

3.3 REF 542+ voltage elements (F27-F59) subrelay

In the ABB REF 542+ relay there are three overvoltage and three undervoltage definite time protection functions; each of them evaluates the phase or line voltage RMS value at the fundamental frequency. Additionally there are two residual overvoltage protection functions.

3.3.1 Available Units

- three definite time overvoltage elements for the phase-ground voltage ("U> phase", "U>> phase", "U>>> phase" block)

- three definite time overvoltage elements for the line-line voltage ("U> line", "U>> line", "U>>> line" block)

- three definite time undervoltage elements for the phase-ground voltage ("U< phase", "U<< phase", "U<<< phase" block)

- three definite time undervoltage elements for the line-line voltage ("U< line", "U<< line", "U<<< line" block)

- two definite time residual overvoltage elements ("UNe1" and "UNe2" block)

3.3.2 Functionality

The PowerFactory ABB REF 542+ relay model implements three overvoltage and three undervoltage protection elements. The ability to evaluate the phase or line voltage RMS value has been implemented in the PowerFactory ABB REF 542+ relay model using two blocks for each relay voltage protection function. Please notice that only one of them can be active at the same time; the other must be disabled manually.

Two residual overvoltage elements are available as well. In this case each protection element is implemented by a block and, of course, they can be active simultaneously.

3.3.3 Data input

The relationships between the relay settings and the model parameters can be found in the following table:

Address	Relay Setting	Model block	Model setting	Note
	Start Value U>	U> phase	Pickup Voltage	
		U> line	Pickup Voltage	
	Time (function 1)	U> phase	Time Delay	
		U> line	Time Delay	
	Start Value U>>	U>> phase	Pickup Voltage	
		U>> line	Pickup Voltage	
	Time (function 2)	U>> phase	Time Delay	
		U>> line	Time Delay	
	Start Value U>>>	U>>> phase	Pickup Voltage	
		U>>> line	Pickup Voltage	
	Time (function 3)	U>>> phase	Time Delay	
		U>>> line	Time Delay	
	Start Value U<	U< phase	Pickup Voltage	
		U< line	Pickup Voltage	

Address	Relay Setting	Model block	Model setting	Note
	Time (function 1)	U< phase	Time Delay	
		U< line	Time Delay	
	Start Value U<<	U<< phase	Pickup Voltage	
		U<< line	Pickup Voltage	
	Time (function 2)	U<< phase	Time Delay	
		U<< line	Time Delay	
	Start Value U<<<	U<<< phase	Pickup Voltage	
		U<<< line	Pickup Voltage	
	Time (function 3)	U<<< phase	Time Delay	
		U<<< line	Time Delay	
	UNe (function 1)	UNe1	Pickup Voltage	
	Time (function 1)	UNe1	Time Delay	
	UNe (function 2)	UNe2	Pickup Voltage	
	Time (function 2)	UNe2	Time Delay	

3.4   REF 542+ frequency (F81) subrelay

The REF 542plus relay can install up to 6 frequency protection elements per protected net. Each frequency protection element can be used to detect frequency variations in a configurable amplitude and/or rate of change frequency range.

The PowerFactory REF 542+ relay model is implementing 6 blocks detecting frequency variations and 6 blocks detecting rate of change frequency.

3.4.1   Available Units

- six overfrequency / underfrequency elements ("Frequency1", "Frequency2". . . "Frequency6" block)

- six frequency gradient elements ("dfdt1","dfdt2". . . "dfdt6" block).

- one frequency measurement element ("Meas Freq" block)

- six "AND" boolean operators ("Logic Frequency 1 AND", "Logic Frequency 2 AND", "Logic Frequency 3 AND", "Logic Frequency 4 AND", "Logic Frequency 5 AND" and "Logic Frequency 6 AND" block)

- six "OR" boolean operators ("Logic Frequency 1 OR", "Logic Frequency 2 OR", "Logic Frequency 3 OR", "Logic Frequency 4 OR", "Logic Frequency 5 OR" and "Logic Frequency 6 OR" block)

3.4.2   Functionality

For each frequency element the user can select which *"Trip criteria"* is used activating or deactivating the subrelay output signals. At this purpose a logic block which combines the uder/overfrequency trip signal and the frequency gradient trip signal using the boolean "AND" operator and a logic block using the "OR" operator are available for each frequency element. An *Undervoltage threshold* setting can be set as well.

3.4.3   Data input

The relationships between the relay settings and the model parameters can be found in the following table:

Address	Relay Setting	Model block	Model setting	Note
	Function x^A Start value	Frequency x^A	Frequency	
	Function x^A Frequency gradient	Frequency x^A	Gradient df/dt	
	Function x^A Time	Frequency x^A	Time delay	
		dfdtx^A	Time delay	
	Function x^A Undervoltage threshold	Block Voltage x^A	Pickup Voltage	

with x^A = element number[1]

Accordingly with the *Trip criteria* relay setting the frequency and the frequency gradient output can be put together by an "AND" boolean operator using the "Logic Frequency 1 AND" , "Logic

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[1]x^A=1,2,3,4,5,6

Frequency 2 AND" . . . "Logic Frequency 6 AND" blocks or by an "OR" boolean operator using the "Logic Frequency 1 OR" , "Logic Frequency 2 OR" . . . "Logic Frequency 6 OR" blocks. If the "AND" logic isn't used "Logic Frequency 1 AND" , "Logic Frequency 2 AND". . . "Logic Frequency 6 AND" must be disabled and "Logic Frequency 1 OR" , "Logic Frequency 2 OR". . . "Logic Frequency 6 OR" must be used instead. If both the "AND" and the "OR" block connected to the output of a given frequency element are disabled, the element is not operating the subrelay output contact and is not able to operate the breaker.

3.5   REF 542+ distance (F21) subrelay

3.5.1   Available Units

- Five distance zones ("Zone 1","Zone 2", "Zone 3", "Autoreclose", " Autoreclose" block)

- One Starting logic element ("Starting" block).

- Directional backup trip element ("Dir backup Time" block)

- Starting backup trip element

- Autoreclosing

3.5.2   Functionality

The REF 542+ distance (F21) subrelay consists of five directional polygonal distance zones with overcurrent starting and polarizing feature.

The backup trip signals operated by the starting element and by the directional element are available as well.

Please notice that the starting logic implemented in the model is a simplified version: only the overcurrent starting is available.

3.5.3   Data input

The relationships between the relay settings and the model parameters can be found in the following table:

Address	Relay Setting	Model block	Model setting	Note
	I>	Starting	IP>	In the "Overcurrent" tab page
	IN>	Starting	IN>	
	Zone 1 Resistance R	Zone 1	+R Resistance	
	Zone 1 Reactance X	Zone 1	+X Reach	
	Zone 1 Angle Delta 1	Zone 1 Angles	Directional Angle, alpha	relay setting =- model setting
	Zone 1 Angle Delta 2	Zone 1 Angles	Directional Angle, phi	
	Zone 1 Time	Zone 1 Timer	Time Setting	
	Zone 1 Direction	Zone 1	Tripping Direction	
	Zone 2 Resistance R	Zone 2	+R Resistance	
	Zone 2 Reactance X	Zone 2	+X Reach	
	Zone 2 Angle Delta 1	Zone 2 Angles	Directional Angle, alpha	relay setting =- model setting
	Zone 2 Angle Delta 2	Zone 2 Angles	Directional Angle, phi	
	Zone 2 Time	Zone 2 Timer	Time Setting	
	Zone 2 Direction	Zone 2	Tripping Direction	
	Zone 3 Resistance R	Zone 3	+R Resistance	
	Zone 3 Reactance X	Zone 3	+X Reach	
	Zone 3 Angle Delta 1	Zone 3 Angles	Directional Angle, alpha	relay setting =- model setting
	Zone 3 Angle Delta 2	Zone 3 Angles	Directional Angle, phi	
	Zone 3 Time	Zone 3 Timer	Time Setting	
	Zone 3 Direction	Zone 3	Tripping Direction	
	Zone Overreach Resistance R	Zone Overreach	+R Resistance	
	Zone Overreach Reactance X	Zone Overreach	+X Reach	

Address	Relay Setting	Model block	Model setting	Note
	Zone Overreach Angle Delta 1	Zone Over-reach Angles	Directional Angle, alpha	relay setting =- model setting
	Zone Overreach Angle Delta 2	Zone Over-reach Angles	Directional Angle, phi	
	Zone Overreach Time	Zone Over-reach Timer	Time Setting	
	Zone Overreach Direction	Zone Over-reach	Tripping Direction	
	Autoreclose Resistance R	Autoreclose	+R Resistance	
	Autoreclose Reactance X	Autoreclose	+X Reach	
	Autoreclose Angle Delta 1	Autoreclose Angles	Directional Angle, alpha	relay setting =- model setting
	Autoreclose Angle Delta 2	Autoreclose Angles	Directional Angle, phi	
	Autoreclose Time	Autoreclose Timer	Time Setting	
	Autoreclose Direction	Autoreclose	Tripping Direction	
	Earth Factor k	Polarizing	K0	
	Earth Factor Angle k	Polarizing	Angle	
	Directional Backup Angle Delta 1	Dir backup	Directional Angle, alpha	relay setting =- model setting
	Directional Backup Angle Delta 2	Dir backup	Directional Angle, phi	
	Directional Backup Time	Dir backup Time	Time Setting	
	Non Directional Backup Time	Backup Time	Time Setting	
	Autoreclose Number of Reclosure cycles	Z Reclosing	Operations to Lockout	Set equal to "Number of Reclosure cycles"+1
	Autoreclose Reclaim Time	Z Reclosing	Reset Time	
	Autoreclose Dead Time First Shot	Z Reclosing	Reclosing Interval 1	
	Autoreclose Dead Time Second Shot	Z Reclosing	Reclosing Interval 2	
	Autoreclose Dead Time Third Shot	Z Reclosing	Reclosing Interval 3	
	Autoreclose Dead Time Fourth Shot	Z Reclosing	Reclosing Interval 4	
	Autoreclose Dead Time Fifth Shot	Z Reclosing	Reclosing Interval 5	
	Autoreclosure Apply autoreclosure function to...	Z Reclosing	Logic	In the "Logic" tab page

Please notice that a separated block ("Z reclosing") has been instanced to implement the reclosing feature for the distance functions. This block must contains the same settings present in the "Ph reclosing" and in the "Earth reclosing" block present in the REF 542+ overcurrent subrelay. The reclosing feature can be disabled putting the block out of service.

3.6   REF 542+ differential (F87) subrelay

3.6.1   Available Units

- One differential block with Ct ratio adapters ("Differential", "Winding 1 adapter", "Winding 2 adapter" block).

- One restricted differential ("Restricted Differential" and "Earth Dir Meas" block)

3.6.2   Functionality

The differential feature implements a double I bias differential characteristic with 2nd and 5th harmonic restraint, unrestrained differential characteristic and CT ratio internal compensation. The CT ratio compensation is performed by the "winding adapter" blocks

The restricted differential is directional controlled.

3.6.3   Data input

The relationships between the relay settings and the model parameters can be found in the following table:

Address	Relay Setting	Model block	Model setting	Note
	Transformer group	Winding 2 Adapter	Transformer Group	
	Primary nominal current	Winding 1 Adapter	Current Transformer Ratio	Set equal to Primary nominal current/"CT sec rated I (i.e. 1)"
	Secondary nominal current	Winding 2 Adapter	Current Transformer Ratio	Set equal to Secondary nominal current/"CT sec rated I (i.e. 1)"
	Threshold current	Differential	Differential Current Base Threshold	
	Unbiased region limit	Differential	Restraint Current 1st Threshold	
	Slightly biased region limit	Differential	Restraint Current 2nd Threshold	
	Heavily biased region slope	Differential	Restraint Percentage 2	
	Second harmonic Threshold block	Differential	2nd Harmonic blocking Threshold	In the "Harmonic blocking" tab page
	Fifth harmonic Threshold block	Differential	5th Harmonic blocking Threshold	In the "Harmonic blocking" tab page
	Unbiased region threshold (REF)	Restricted Differential	Differential Current Base Threshold	
	Unbiased region limit	Restricted Differential	Restraint Current 1st Threshold	
	Slightly biased region slope	Restricted Differential	Restraint Percentage 1	
	Slightly biased region limit	Restricted Differential	Restraint Current 2nd Threshold	

Address	Relay Setting	Model block	Model setting	Note
	Heavily biased region slope	Restricted Differential	Restraint Percentage 2	
	Relay operate angle	Earth Dir Meas	Angle Operating Sector	

Please notice that the differential "Restraint percentage 1" (slope of the Slightly biased region) must be calculated manually taking care of the values of the "Threshold current " and of the "Slightly biased region threshold" relay setting.

3.7   Output logic

The output logic is implemented by the "Output Logic" block located in the main relay.

3.7.1   Available Units

- Output Logic

3.7.2   Functionality

The "Output Logic" block is operating the breaker.

3.7.3   Data input

No user input is required to configure the output logic feature.

Please disable the "Output Logic" block located in the main relay to disable the relay model ability to open the power circuit.

4   Features not supported

4.1   REF 542+ overcurrent subrelay

The following features are not supported:

- DOC functions
- Trip characteristic definition using A,B,P
- Inverse type reset characteristic
- Inrush blocking
- Motor protection
- Unbalanced load protection
- Low load protection
- Directional power protection

4.2   REF 542+ voltage elements (F27-F59) subrelay

The following features are not supported:

- Overvoltage/undervoltage elements ability to operate as single phase or double phase
- Synchronism check
- Switching resonance protection

4.3   REF 542+ frequency (F81) subrelay

The following features are not supported:

- High harmonic protection
- Frequency supervision

4.4   REF 542+ distance (F21) subrelay

The following features are not supported:

- Directional memory
- Starting phase selection and undervoltage starting
- Distance element "Second Setting" values
- Directional Backup Direction

4.5   REF 542+ differential (F87) subrelay

The following features are not supported:

- Differential Slightly biased region threshold

- Restricted earth fault CT ratio compensation

- Restricted earth fault "Time" setting

5 References

[1] ABB Oy Distribution Automation, P.O.box 699, FI-65101 Vaasa , FINLAND. *REF 542plus Multifunction Protection and Switchgear Control Unit Protection Functions Configuration and Settings Protection manual 1MRS755860 Version: D/19.12.2008*, 2008.