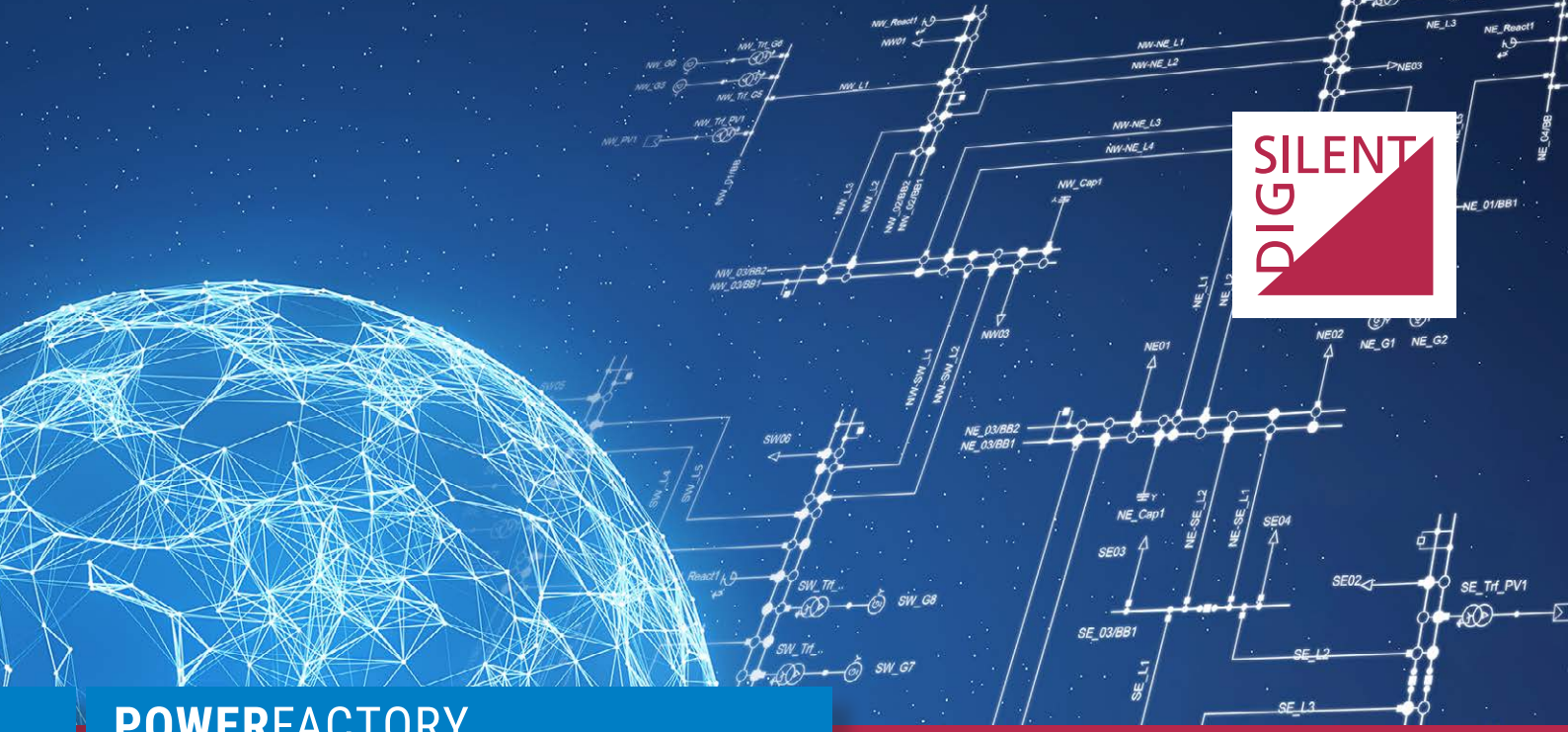


# PowerFactory 2021

## Technical Reference

### ABB SPAD 346

PF2021

**POWER SYSTEM SOLUTIONS**

MADE IN GERMANY

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# Contents

# 1 Model information

**Manufacturer** ABB

**Model** SPAD 346

**Variants** This PowerFactory relay model type can be used to simulate the ABB SPAD 346 relay which is a protection assembly containing the differential relay module SPCS 3D53, the earth fault relay module SPCD 2D55 and the combined overcurrent and earth fault relay module SPCJ 2D28.

# 2 General description

The ABB SPAD 346 is a integrated three phase differential relay, three phase overcurrent relay and multi-configurable earth fault relay. The stabilized differential relay module provides winding short circuit and interturn fault protection for two winding power transformers and generator-transformers units and inter winding short circuit protection for generators. The earth fault relay module provides protection for transformers HV and LV side according to the principle selected: stabilized differential current principle, high impedance principle, residual current principle or neutral current principle. The three stage overcurrent module provides protection for power transformers and generators. The two stage earth fault protection provides an additional backup feature.

The ABB SPAD 346 relay has been modeled using one PowerFactory relay model which includes the measurement and acquisition elements, the differential features, with harmonic restraint and vector group/ratio compensation, the phase and ground overcurrent elements, the phase discontinuity element and the output logic.

The ABB SPAD 346 PowerFactory relay model is a monolithic relay. In the schemes are graphically marked the 3 protective modules (SPCS 3D53, SPCD 2D55 and SPCJ 2D28).

The model implementation has been based on the information available in the relay documentation provided by the manufacturer and freely available [1].

# 3 Supported features

## 3.1 Measurement and acquisition

It represents the interface between the power system and the relay protective elements. The currents flowing in the power system are converted by two elements modeling two 3 phase CTs and by three elements modeling single phase CTs; the secondary currents are then measured by height elements modeling the digital filters of the relay.

### 3.1.1 Available Units

- Two 3 phase current transformers (”Winding 1 Ct” and ”Winding 2 Ct” block).
- Three single phase current transformers (”Winding 1 EarthCt”, ”HV Side Neutral Ct” and ”LV Side Neutral Ct” block).
- Eight measurement elements (”Measure 1”, ”Measure 2”, ”Measure HV neutral”, ”Measure LV neutral”, ”Diff 2nd Harmonic 1”, ”Diff 2nd Harmonic 2”, ”HV Neutral 2nd Harmonic” and ”LV Neutral 2nd Harmonic” block).

### 3.1.2 Functionality

The ”Winding 1 Ct”, the ”Winding 2 Ct”, the ”Winding 1 EarthCt”, ”HV Side Neutral Ct” and ”LV Side Neutral Ct” represent ideal CTs. Using the CT default configuration the current at the primary side are converted to the secondary side using the CT ratio. The CT saturation and/or its magnetizing characteristic are not considered. Please set the "Detailed Model" check box in the "Detailed Data" tab page of the CT dialog and insert the data regarding the CT burden, the CT secondary resistance and the CT excitation parameter if more accurate simulation results are required.

The input currents are sampled at 40 samples/cycle.

Two 3 phase measurement elements (”Measure 1” and ”Measure 2” block) measure, using a DFT filter operating over a full cycle, the fundamental harmonic of the phase currents converted by two different 3 phase CTs. The first measurement element measures also the zero sequence current converted by the ”Winding 1 EarthCt” CT. Two separated measurement elements (”Diff 2nd Harmonic 1” and ”Diff 2nd Harmonic 2” block) extracts with the DFT filter the $2^{nd}$ harmonic current components which are used as differential constraints.

Two single phase measurement elements (”Measure HV neutral” and ”Measure LV neutral”) measure, using a DFT filter operating over a full cycle, the fundamental harmonic of the neutral currents converted by two different single phase CTs. Two separated measurement elements (”HV Neutral 2nd Harmonic” and ”LV Neutral 2nd Harmonic” block) extracts with the DFT filter the $2^{nd}$ harmonic current components which are used as restricted earth fault differential constraints.

To summarize with different criteria, there is one measurement element for each 3 phase Ct, and one measurement element for each single phase Ct; in both cases one additional measurement element extracts the $2^{nd}$ harmonic current:

- ”Measure 1” (fundamental frequency of the currents converted by ”Winding 1 Ct”).
- ”Diff 2nd Harmonic 1” ($2^{nd}$ harmonic of the currents converted by ”Winding 1 Ct”).

- ”Measure 2” (fundamental frequency of the currents converted by ”Winding 2 Ct”).
- ”Diff 2nd Harmonic 2” ($2^{nd}$ harmonic of the currents converted by ”Winding 2 Ct”).
- ”Measure HV neutral” (fundamental frequency of the current converted by ”HV Side Neutral Ct”).
- ”HV Neutral 2nd Harmonic” ($2^{nd}$ harmonic of the current converted by ”HV Side Neutral Ct”).
- ”Measure LV neutral” (fundamental frequency of the current converted by ”LV Side Neutral Ct”).
- ”LV Neutral 2nd Harmonic” ($2^{nd}$ harmonic of the current converted by ”LV Side Neutral Ct”).

### 3.1.3 Data input

The CT secondary rated current (1 or 5 A) value must be set in the measurement elements (*”Nominal current”* parameter).

## 3.2 Protective elements

Three differential elements with current adapters and ancillary RMS calculation elements simulate the relay differential features. Some auxiliary phase and earth over current elements are also present in the model.

### 3.2.1 Available Units

- One 3 phase differential element (”Differential” block).
- Two 3 phase current adapters for the differential element (”Winding 1 Adapter” and ”Winding 2 Adapter” block).
- Two 3 phase measurement elements (”Diff RMS meas” and ”Stab RMS meas” block, ancillary to the differential element).
- Two restricted earth fault elements (”Earth Fault Differential HV side” and ”Earth Fault Differential HV side” block).
- Two single phase current adapters for the restricted earth fault differential element (”Winding 1 REF Adapter” and ”Winding 2 REF Adapter” block).
- Two single phase measurement elements (”REF HV Diff RMS meas” and ”REF HV Diff RMS meas” block, ancillary to the restricted earth fault differential element).
- One 3 phase inverse time overcurrent element (”I> ” block).
- Two 3 phase definite time overcurrent element (”I>>” and ”I>>>” block).
- One ground inverse time overcurrent element (”Io> ” block, fed by the ”Winding 1 EarthCt” CT).
- Two ground definite time overcurrent elements (”Io>> ” and ”Io>>>” block, fed by the ”Winding 1 EarthCt” CT).
- One definite time discontinuity current(”Phase discontinuity”block).

### 3.2.2 Functionality

**Differential** :

The following features are available in the differential element (”Differential” block):

- Double bias current percentage restrained differential with user configurable differential threshold, second restraint slope thresholds and first slope percentage.
- Unrestrained differential with user configurable threshold.
- $2^{nd}$ harmonic restraint of the first differential with user configurable threshold.

The following features are available in the restricted earth fault differential elements (”Earth Fault Differential HV side” and ”Earth Fault Differential LV side” block):

- Single bias current percentage restrained differential with user configurable differential threshold and time delay.

- $2^{nd}$ harmonic restraint with user configurable threshold.

The two current adapters get the vector values and the RMS values measured by ”Measure 1” and by ”Measure 2” and recalculate them taking care of the different CT ratios, voltage levels and CT winding connections.

A logic element (”differential I calculator” block) get the current adapters output signals and calculates the differential current vector values; such values are then used by a measurement element (”Diff RMS meas” block) which calculates the RMS value of the differential current. A similar sequence is used to calculate the stabilizing current values: a logic element (”stabilizing I calculator” block) get the current adapters output signals and calculates the stabilizing current vector values; such values are then used by a measurement element (”Stab RMS meas” block) which calculates the RMS value of the stabilizing current.

The differential element get both the differential current values and the stabilizing current values. The average values are then used to calculate the differential threshold considering the user configurable double bias current percentage restraint.

**Overcurrent** :

The 3 phase inverse time overcurrent element (”I> ” block) and the earth fault inverse time overcurrent element (”Io> ” block) support the following inverse characteristics:

- IEC long time inverse
- IEC very inverse
- IEC extremely inverse
- Definite time (51)
- IEC normal inverse
- RI inverse
- RXIDG

The inverse time trip characteristic equations comply with the IEC standard equations.

The discontinuity current is calculated accordingly with the documentation provided by ABB.

### 3.2.3 Data input

The relationships between the relay settings and the model parameters can be found in the following table (the relay model parameter names are listed between brackets):

**Differential** :

| Address | Relay Setting | Model block | Model Parameter | Note |
|---|---|---|---|---|
| | CT ratio correction on power transformer HV side $I_1/I_n$ | Winding 1 Adapter | Current Transformer Ratio (CTratio) | |
| | CT ratio correction on power transformer HV side $I_2/I_n$ | Winding 2 Adapter | Current Transformer Ratio (CTratio) | |

| Address | Relay Setting | Model block | Model Parameter | Note |
|---|---|---|---|---|
| | Stabilized differential current stage 3 $\Delta$I> | Differential | Differential Current base threshold (Idiff) | |
| | Basic Start ratio P/$I_n$ | | | |
| | Starting ratio setting S | Differential | Restrain Percentage 1 (Irestepercent1) | |
| | Second turning point $I_{2tp}/I_n$ of characteristic curve | Differential | Restraint Current 2nd Threshold (Ipset2) | |
| | Harmonics blocking ratio $I_{d2f}/I_{d1f}$ | Differential | 2nd Harmonic blocking threshold (H2threshold) | In the "Harmonic blocking" tab page |
| | Instantaneous differential current stage 3$\Delta I$>> | Differential | Unrestrained Differential threshold (Idiffunrest) | |
| | Correction of HV side phase CT ratio $I_1/I_n$ | Winding 1 Adapter | Current Transformer Ratio (CTratio) | |
| | Correction of LV side phase CT ratio $I_1/I_n$ | Winding 2 Adapter | Current Transformer Ratio (CTratio) | |
| | Earth fault stabilized differential current | Earth Fault Differential HV side | Differential Current base threshold (Idiff) | |
| | Basic Start ratio on HV side $P_1/I_n$ | | | |
| | Operate time setting on HV side $t_{01}$> | Earth Fault Differential HV side | Time Setting (Tset) | |
| | Second harmonics restraint ratio $I_{2f}/I_{1f}$ | Earth Fault Differential HV side | 2nd Harmonic blocking threshold (H2threshold) | In the "Harmonic blocking" tab page |
| | on HV side neutral current $I_{01}$ | | | |
| | Earth fault stabilized differential current | Earth Fault Differential LV side | Differential Current base threshold (Idiff) | |
| | Basic Start ratio on LV side $P_1/I_n$ | | | |
| | Operate time setting on LV side $t_{01}$> | Earth Fault Differential LV side | Time Setting (Tset) | |
| | Second harmonics restraint ratio $I_{2f}/I_{1f}$ | Earth Fault Differential LV side | 2nd Harmonic blocking threshold (H2threshold) | In the "Harmonic blocking" tab page |
| | on LV side neutral current $I_{01}$ | | | |

**Overcurrent** :

| Address | Relay Setting | Model block | Model Parameter | Note |
|---|---|---|---|---|
| | Stage I> Start Current | I> | Current Setting (Ipset) | |
| | Stage I> Operate time at time definite time characteristic | I> | Time Dial (Tpset) | |
| | Stage I> Time multiplier k | I> | Time Dial (Tpset) | |
| | Time/current characteristic at inverse time mode | I> | Characteristic (pcharac) | |
| | Stage I>> Start Current | I>> | Pickup Current (Ipset) | |
| | Stage I>> operate time at time definite characteristic | I>> | Time Setting (Tset) | |
| | Stage I>>> Start Current | I>>> | Pickup Current (Ipset) | |
| | Stage I>>> operate time at time definite characteristic | I>>> | Time Setting (Tset) | |
| | Stage Io> Start Current | Io> | Current Setting (Ipset) | |
| | Stage Io> Operate time at time definite time characteristic | Io> | Time Dial (Tpset) | |
| | Stage Io> Time multiplier k | Io> | Time Dial (Tpset) | |
| | Time/current characteristic at inverse time mode | Io> | Characteristic (pcharac) | |
| | Stage Io>> Start Current | Io>> | Pickup Current (Ipset) | |
| | Stage Io>> operate time | Io>> | Time Setting (Tset) | |

| Address | Relay Setting | Model block | Model Parameter | Note |
|---|---|---|---|---|
| | at time definite characteristic<br>Stage Δ I> Start Current<br>Stage Δ I> operate time<br>at time definite characteristic | <br>Phase discontinuity<br>Phase discontinuity | <br>Pickup Current (Ipset)<br>Time Setting (Tset) | |

## 3.3 Output logic

It represents the output stage of the relay; it's the interface between the relay and the power breaker. A set of five relay output contacts is available and can be configured using any custom logic.

### 3.3.1 Available Units

- One output element ("Logic" block).

### 3.3.2 Functionality

The "Logic" block gets the trip signals coming from the differential element and from the overcurrent elements; it operates the relay output contacts and the power breaker.

The following output contacts are available:

- OUT1
- OUT2
- OUT3
- OUT4
- OUT5

They are operated by any (differential element or overcurrent /overload elements) protection element trip. By default the behavior of these output contacts is identical. Any custom relay output logic can be inserted in the "Logic" tab page of the "Logic" block.

The relay output contact which operates the breaker is "OUT1".

### 3.3.3 Data input

To disable completely the relay model ability to open the power circuit breaker disable the "Logic" block.

# 4 Features not supported

The following features are not supported:

- $5^{th}$ harmonic restraint.
- Circuit breaker failure protection.

Please notice that the CT adaptor in the relay is using a simpler technique than the logic implemented inside the PF CT adapter block: in the relay the windings type isn't available but only a multiplier is provided.

# 5 References

[1] ABB Substation Automation Oy, P.O. Box 699, FI-65101 Vaasa , FINLAND. *Stabilized Differential Relay SPAD 346 1MRS 750398-MBG Issued: April 1999*, 1999.