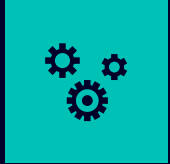




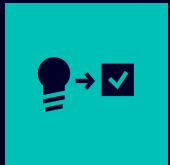
EXPERT WORKSHOP SERIES

Part 3: Line Differential Protection - Configuration and Testing

Agenda



Device Configuraton – DIGSI 5 Demo



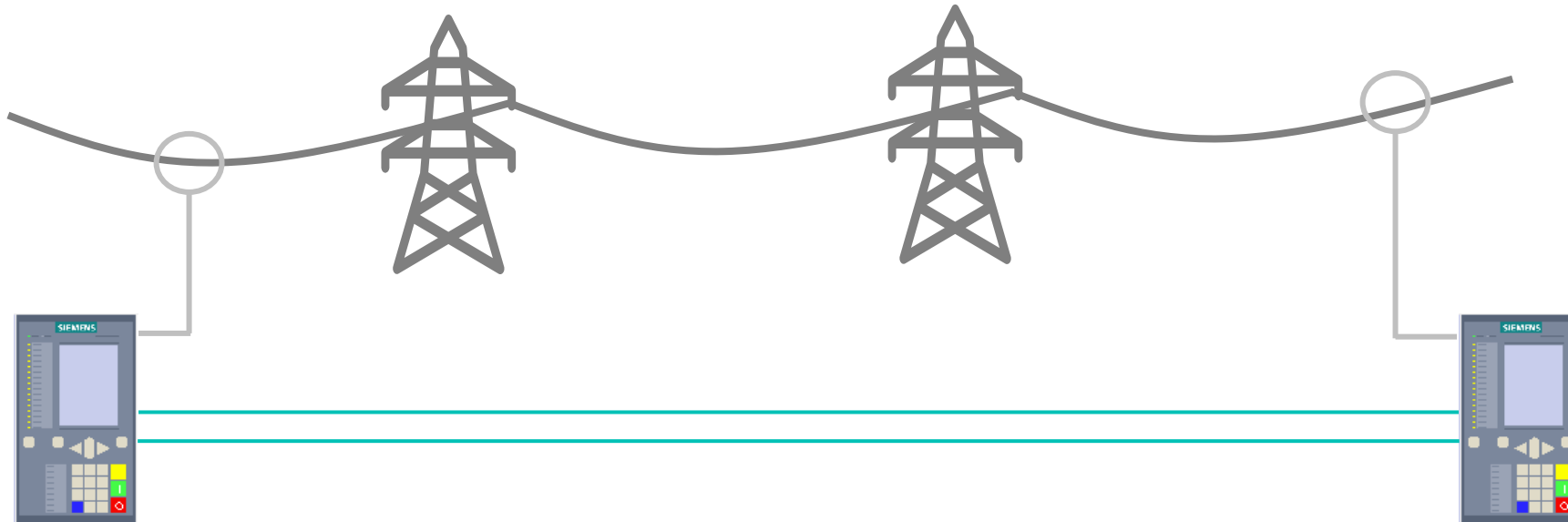
Functional Testing – SIPROTEC 5 Digital Twin



Fault Analysis – SIGRA

Device Configuration DIGSI 5 Demo

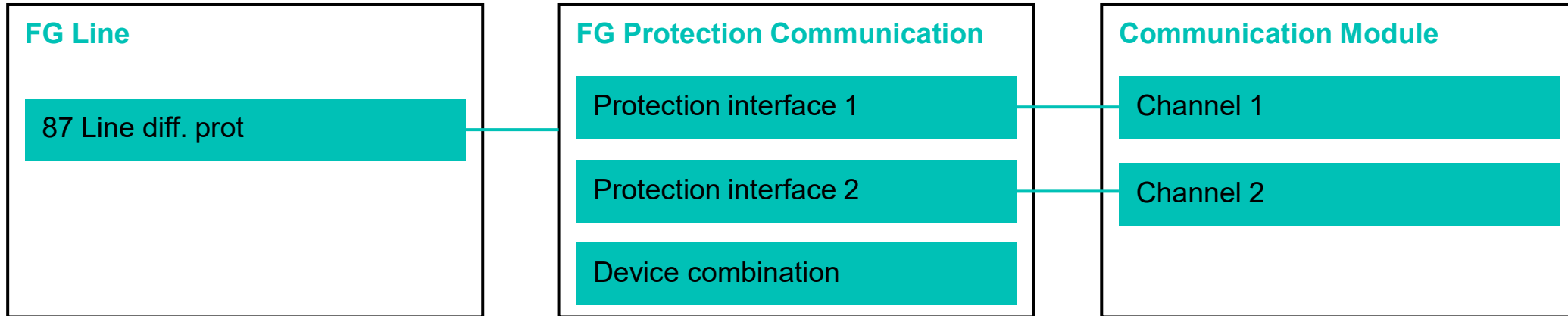
Example: 400 kV Overhead Line



- 2-End Line Differential Protection
- Direct, single-mode optical fiber, USART-AV-2LDFO communication module
- Redundant communication channels

SIPROTEC 5 device: 7SD87-DAAA-AA0-0AAAA0-AJ1111-13111A-VAA000-000AC0-CH1BA1

PI Configuration: Advanced Protection Interface



- A **FG Line** is routed to a **FG Protection Communication**
- A **FB Protection Interface** within a **FG Protection Communication** is assigned to a channel within a **Communication module**
- Multiple instances of these FGs and FBs possible in one device

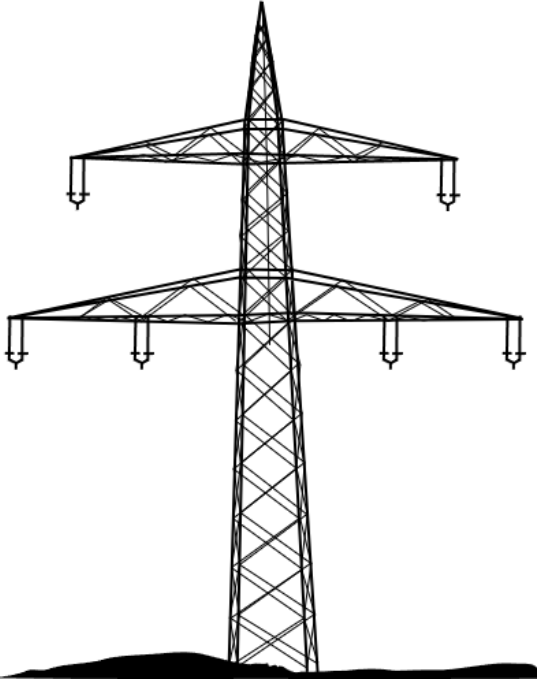
FG: Function Group

FB: Function Block

Recommended settings for Current Transformer Classes

Transformer Class	STANDARD	Ratio Error at Rated Current	Angle Error at Rated Current	Fault at Rated Overcurrent Factor	Fault Transition ³⁰	CT error A ³⁰	CT error B ³⁰
5P	IEC 60044-1	1.0 %	± 60 min	≤ 5 %	1.50	3.0 %	10.0 %
10P		3.0 %	–	≤ 10 %	1.50	5.0 %	15.0 %
TPX		0.5 %	± 30 min	ε ≤ 10 %	1.50	1.0 %	15.0 %
TPY		1.0 %	± 30 min	ε ≤ 10 %	1.50	3.0 %	15.0 %
TPZ		1.0 %	180 min ± 18 min	ε ≤ 10 % (only I ≈)	1.50	6.0 %	20.0 %
PX		IEC 60044-1 OV: Class X				1.50	3.0 %
C100 to C800	ANSI				1.50	5.0 %	15.0 %
5TPE	IEC 61869-10	1.0 %	± 60 min	≤ 5 %	1.50	5.0 %	15.0 %

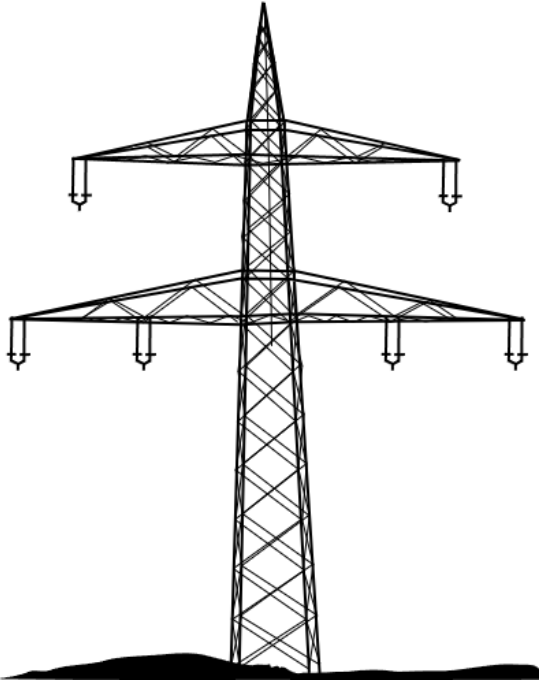
Example: 400 kV Overhead Line



Danube pylon
 Quad bundle
 264-AL1/34-ST1A

Rated voltage	400 kV
Rated current	600 A
C1 per length unit	14,2 nF/km
C0 per length unit	14,2 nF/km
R per length unit	27,3 mΩ/km
X per length unit	0,254 Ω/km
Line length	100 km
Line angle	$\varphi = \tan^{-1} \left(\frac{X_L}{R_L} \right) = 83,9^\circ$
CT ratio	1000 A / 1 A
CT class	5P

Example: 400 kV Overhead Line



Danube pylon
Quad bundle
264-AL1/34-ST1A

Rated voltage	400 kV
C1 per length unit	14,2 nF/km
Line length	100 km

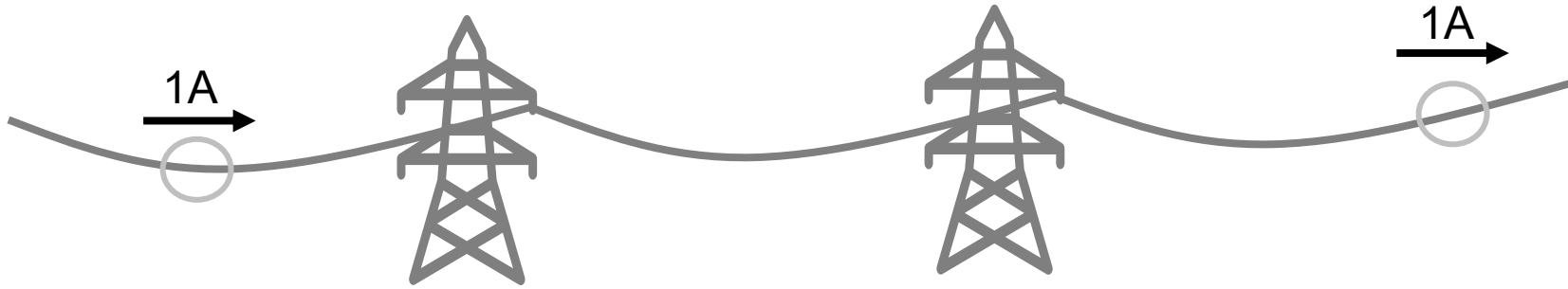
Nominal capacitive charging current

$$I_C = \omega C'_1 \cdot l \cdot \frac{U_N}{\sqrt{3}}$$

$$I_C = 2\pi \cdot 50 \text{ Hz} \cdot 14,2 \text{ nF/km} \cdot 100 \text{ km} \cdot \frac{400 \text{ kV}}{\sqrt{3}} = 103 \text{ A}$$

Functional Testing SIPROTEC DigitalTwin

Normal Load Condition

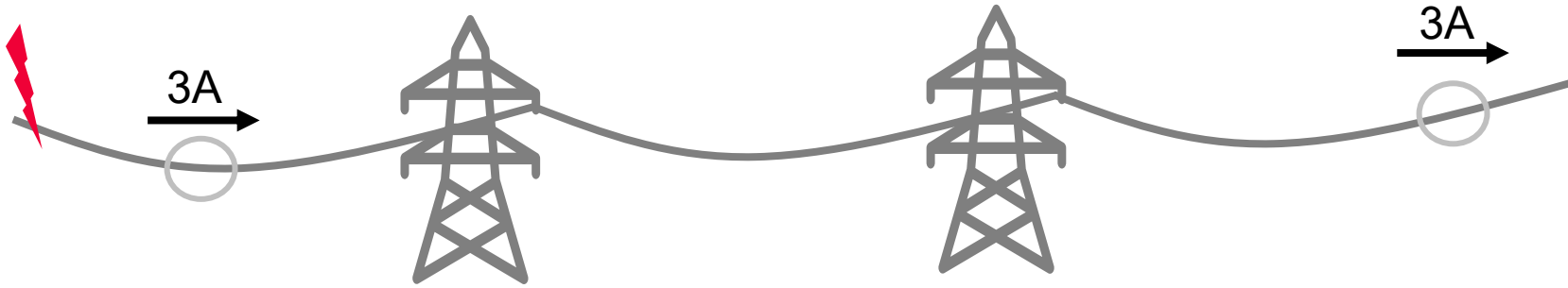


$$I_{\text{rest}} = I_{\text{thr}} + \sum_n I_{\text{ph,CTerr,max}} + \sum_n I_{\text{ph,SigDist,max}} + I_{\text{sync}}$$

$$= 0,258 \text{ A (secondary)} + 2 \cdot (1 \text{ A} \cdot 3\%) = 0,318 \text{ A (secondary)}$$

$$0,318 \text{ A (secondary)} = 0,318 \text{ A} \cdot \frac{1000 \text{ A}}{1 \text{ A}} = 318 \text{ A (primary)} = \frac{318 \text{ A}}{600 \text{ A}} = 53\%$$

External Fault Condition

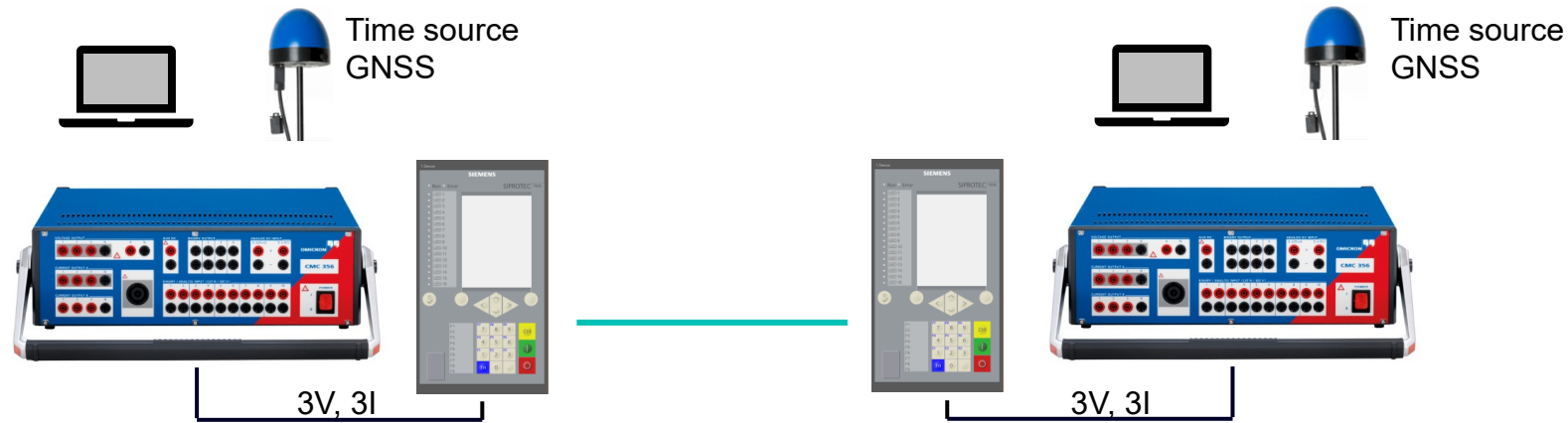


$$I_{\text{rest}} = I_{\text{thr}} + \sum_n I_{\text{ph,CTerr,max}} + \sum_n I_{\text{ph,SigDist,max}} + I_{\text{sync}}$$

$$= 0,258 \text{ A (secondary)} + 2 \cdot (3 \text{ A} \cdot 10\%) = 0,858 \text{ A (secondary)}$$

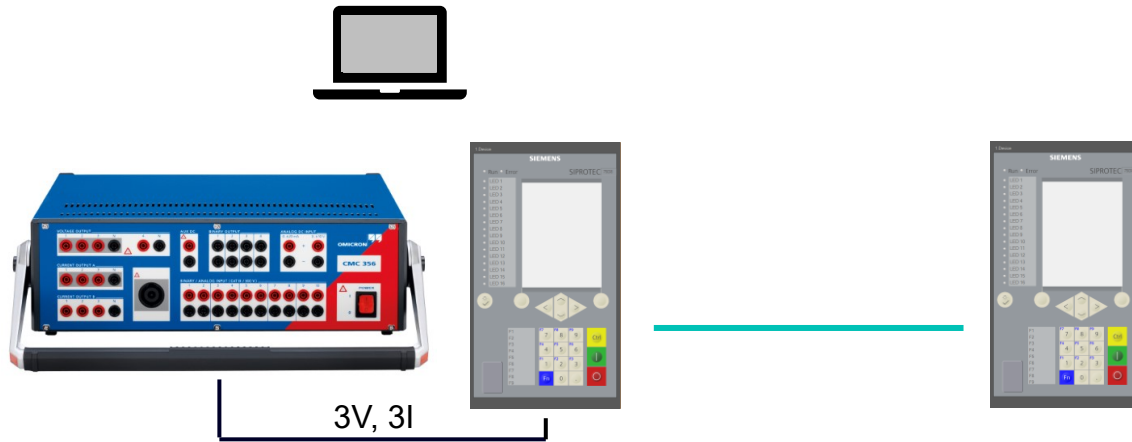
$$0,858 \text{ A (secondary)} = 0,858 \text{ A} \cdot \frac{1000 \text{ A}}{1 \text{ A}} = 858 \text{ A (primary)} = \frac{858 \text{ A}}{600 \text{ A}} = 143\%$$

Test Mode: All Devices



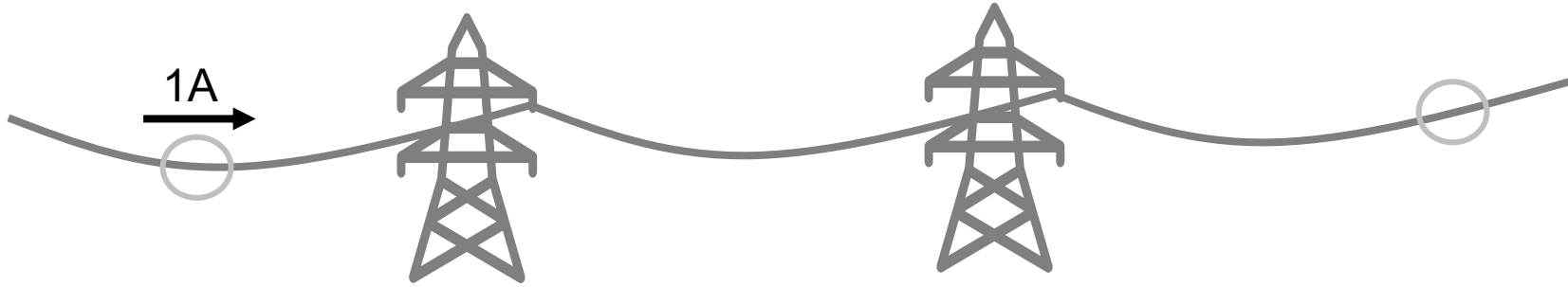
- 1 Check the setting „Action on Behavior = test“
- 2 Activate the test mode in both devices
- 3 Execute comprehensive functional end-to-end tests

Test Mode: Local Device



- 1 Check the setting „Action on Behavior = test“
- 2 Activate the test mode in the local device
- 3 Locally injected test currents are seen as differential currents

Normal Load Condition

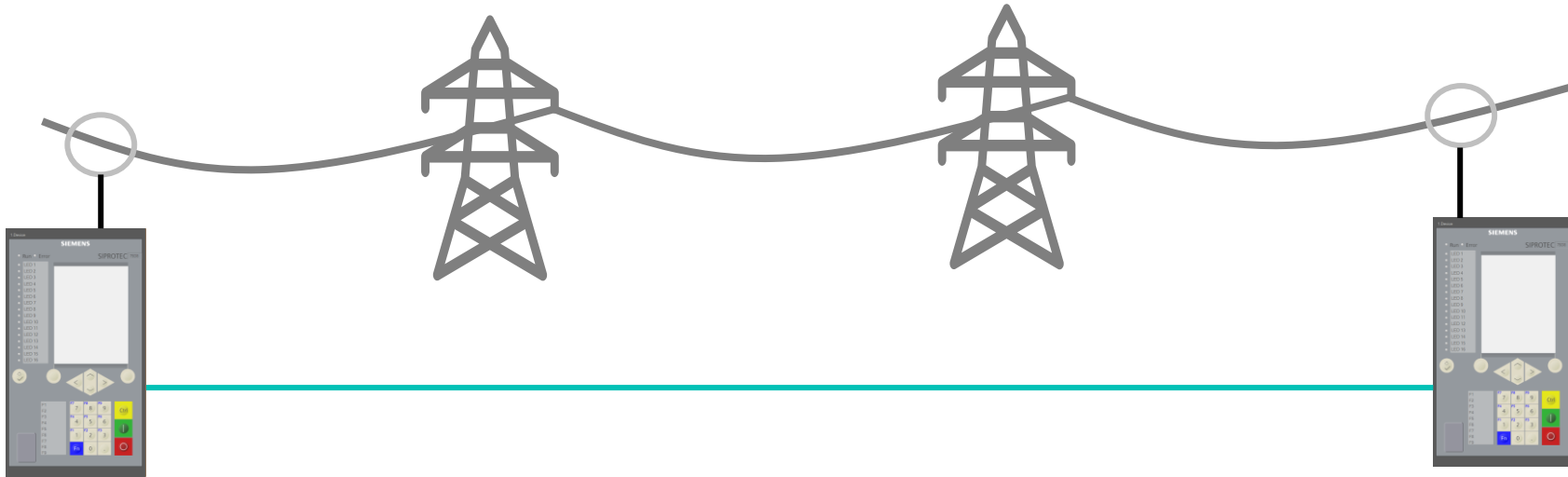


$$I_{\text{rest}} = I_{\text{thr}} + \sum_n I_{\text{ph,CTerr,max}} + \sum_n I_{\text{ph,SigDist,max}} + I_{\text{sync}}$$
$$= 0,258 \text{ A (secondary)} + 1 \text{ A} \cdot 3\% = 0,288 \text{ A (secondary)}$$

$$288 \text{ A (primary)} = \frac{288 \text{ A}}{600 \text{ A}} = 48\%$$

$$I_{\text{Diff}} = 1 \text{ A (secondary)} = 1000 \text{ A (primary)} = \frac{1000 \text{ A}}{600 \text{ A}} = 167\%$$

Checking the Operating Point



- 1 Activate the “Check operating point” test mode in the local device
- 2 The functions 87L in the remote devices are automatically set to this test mode
- 3 Line differential protection remains active, but no operate indications are generated

Fault Analysis SIGRA

Internal Fault Condition



State 1: Normal load condition

State 2: Internal fault condition – fault is fed from both sides

Line Differential Protection webinar series

Links to all webinars of the series

- **Part 1: Line Differential Protection - Basics**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part/b1f36e4f86751bac5b5b>
- **Part 2: Line Differential Protection - Interfaces**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-1/5101ce29a70e0f2f0c95>
- **Part 3: Line Differential Protection - Configuration and Testing**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-2/a155d5a3afa6d0d61295>
- **Part 4: Line Differential Protection - Compatibility of SIPROTEC 4 and SIPROTEC 5**
<https://smartinfrastucture.webinar.siemens.com/line-differential-protection-part-3/a582c41832151fbce672>
- **Bonus Live Q&A Session - Line Differential Protection**
<https://smartinfrastucture.webinar.siemens.com/live-qa-session-line-differential/478dbe71dc403bfb8940>

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