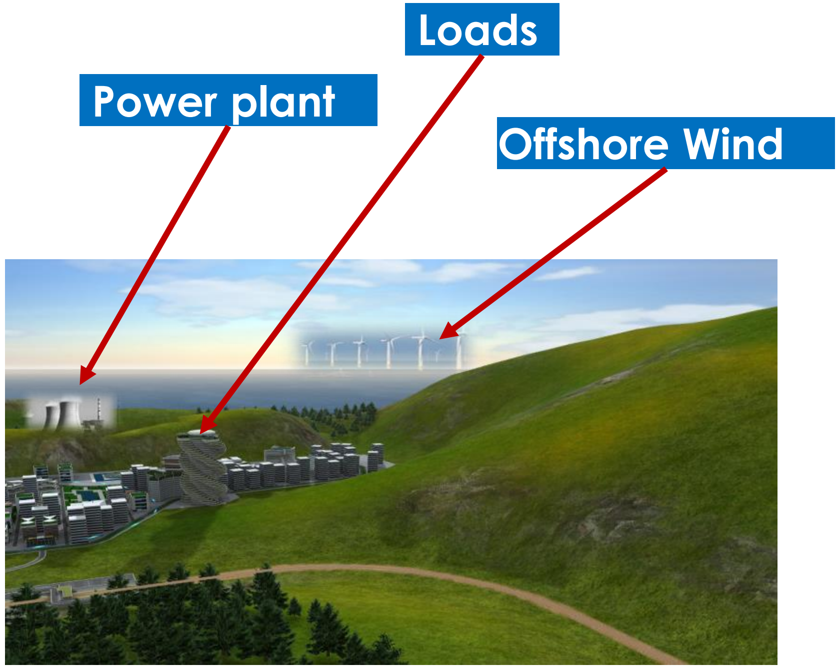
New Smart Multi-Ended Differential Protection for Power Networks

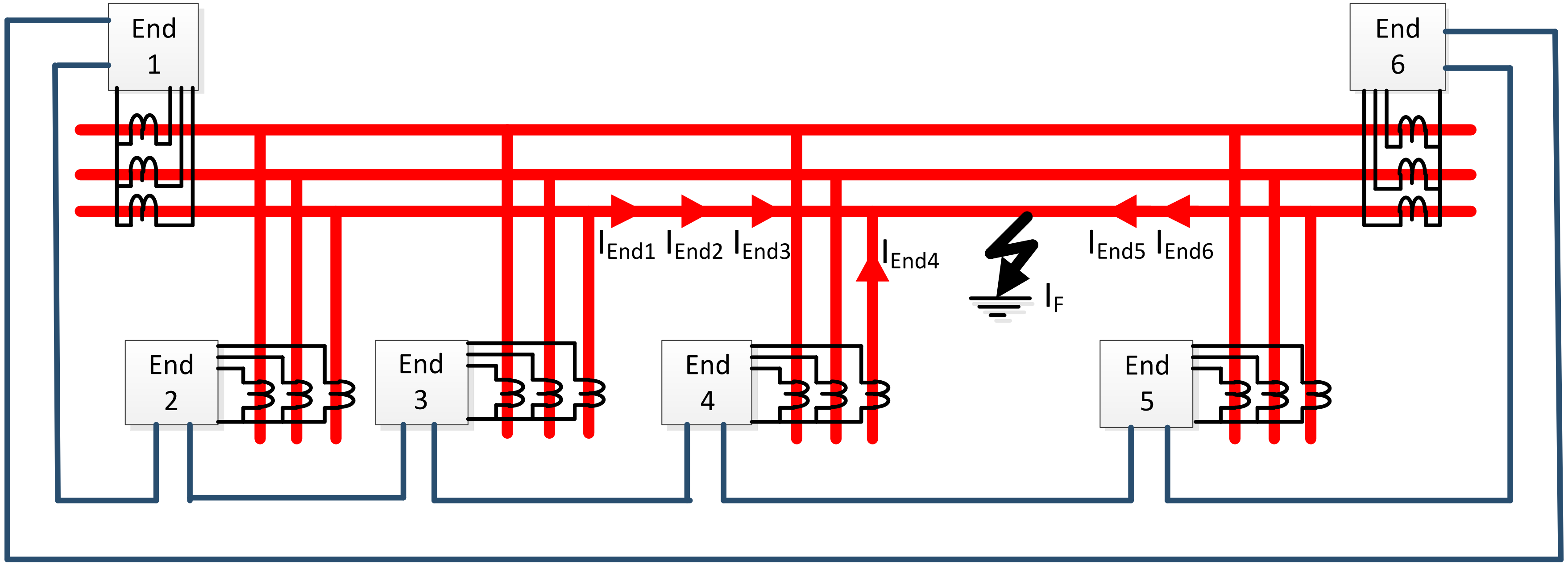
23 May 2017

Introduction
Why multi-ended protection ?

- Utility power networks are evolving to transport power in ever more complex ring and meshed networks.
- For circuits which neighbour the coast, or other potential windfarm locations, those will be candidates for teed feeds to evacuate renewable energy.
- Line/cable differential protection becomes increasingly attractive, with its inherent ability to address grading/selectivity challenges and scalability for multi-terminal circuits to accommodate many connections of distributed needed.



Line Differential Protection Principle

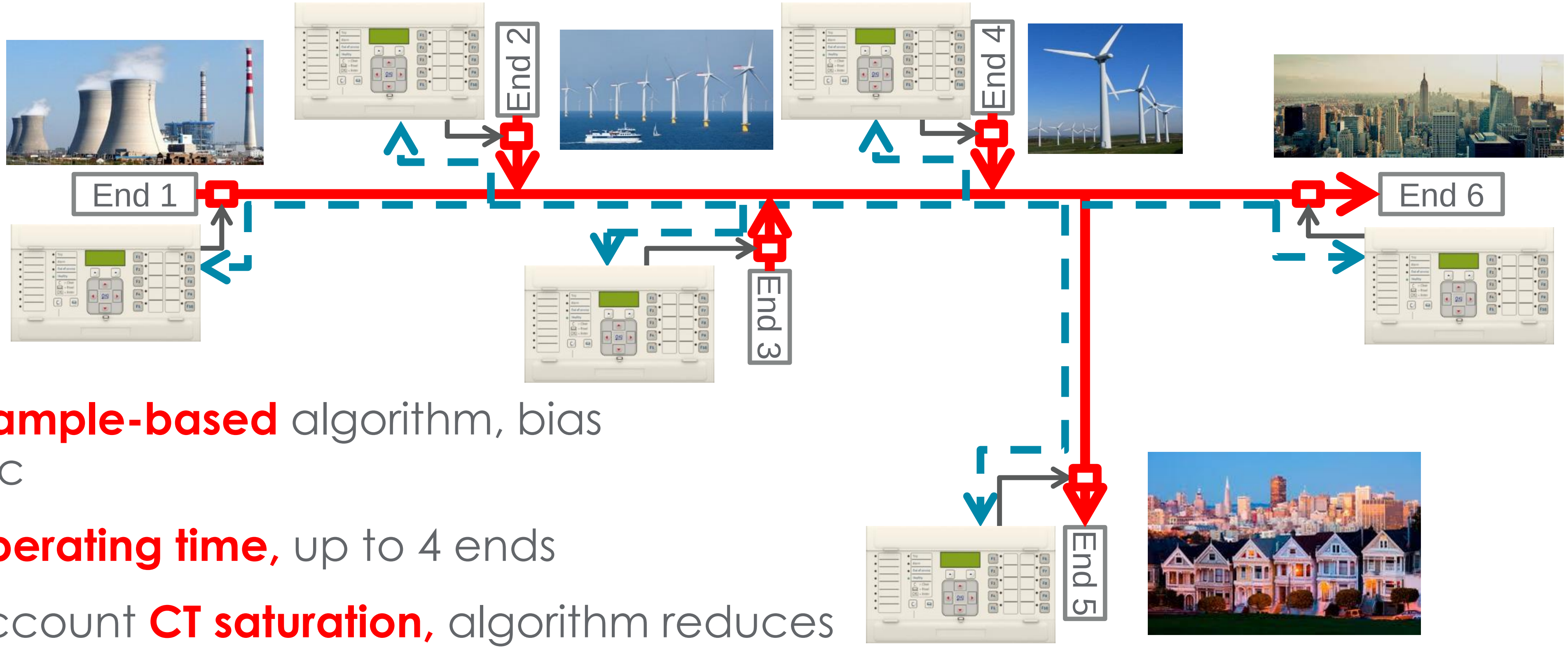


$I_{End1} + I_{End2} + I_{End3} + I_{End4} + I_{End5} + I_{End6} = 0$ Healthy

$I_{End1} + I_{End2} + I_{End3} + I_{End4} + I_{End5} + I_{End6} \neq 0$ Fault

needed.

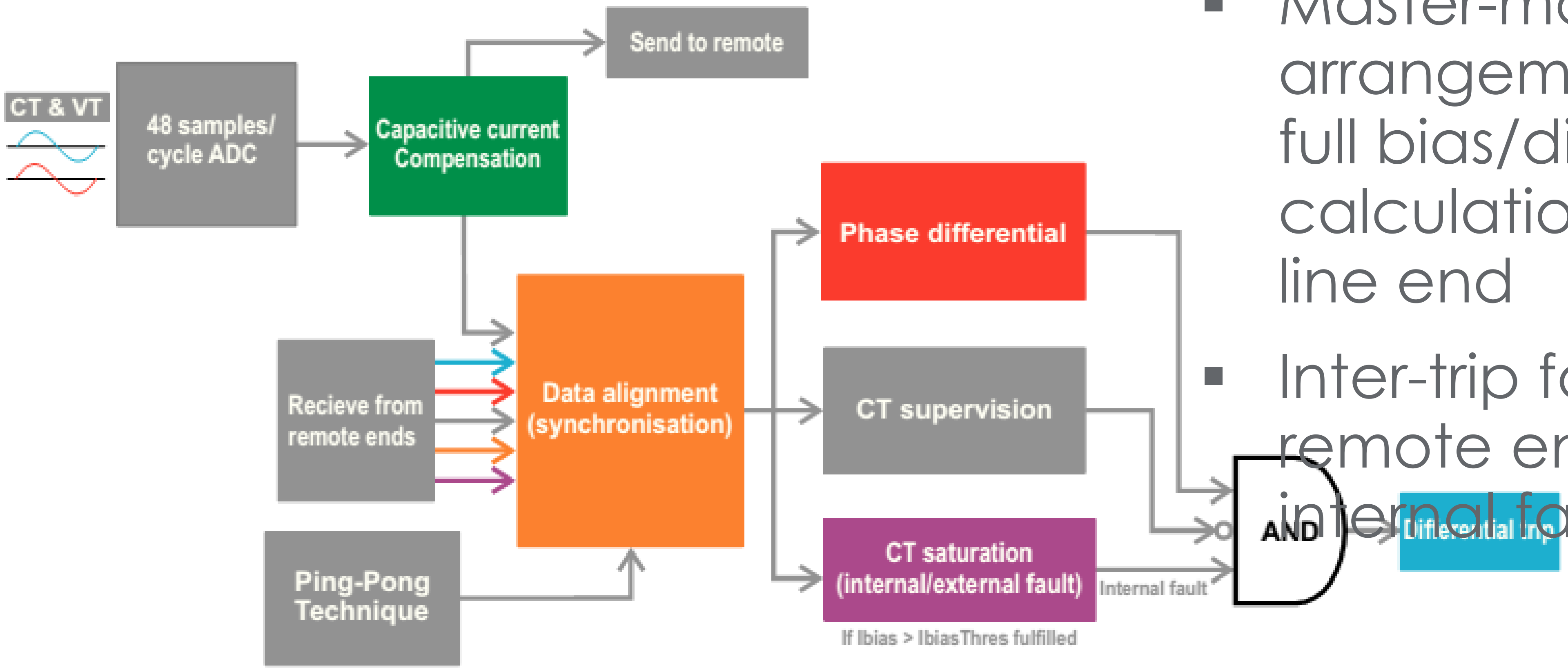
New Multi-ended Differential Protection Highlights



- Innovative **sample-based** algorithm, bias characteristic
- **Sub cycle operating time,** up to 4 ends
- Takes into account **CT saturation,** algorithm reduces CT requirements
- **Capacitive current compensation** with voltage input

needed.

New Multi-end Differential Protection Overview



- Master-master arrangement with full bias/diff calculation at each line end
- Inter-trip for all remote ends for internal faults

needed.

New Multi-end Differential Protection
Phase Differential

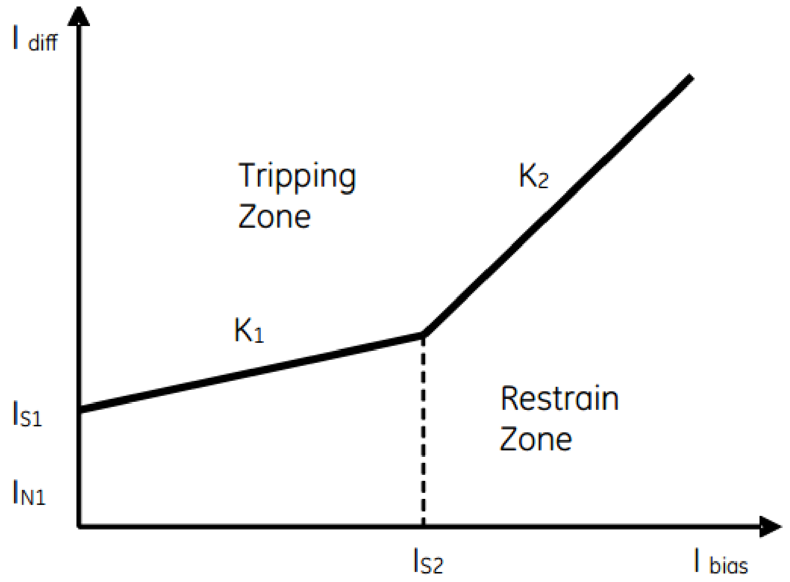
- Bias and differential currents derived from samples, with RMS calculation

$$i_{diff}(n) = \sum_{m=1}^{M} i_{Tm}(n)$$

$$I_{diff}(n) = \sqrt{\frac{1}{N}\sum_{k=n-N+1}^{n} \left|i_{diff}(k)\right|^2}$$

$$I_{Tm}(n) = \sqrt{\frac{1}{N}\sum_{k=n-N+1}^{n} \left|i_{Tm}(k)\right|^2}$$

$$I_{bias}(n) = \frac{1}{2}\left[\sum_{m=1}^{M} I_{Tm}(n)\right]$$



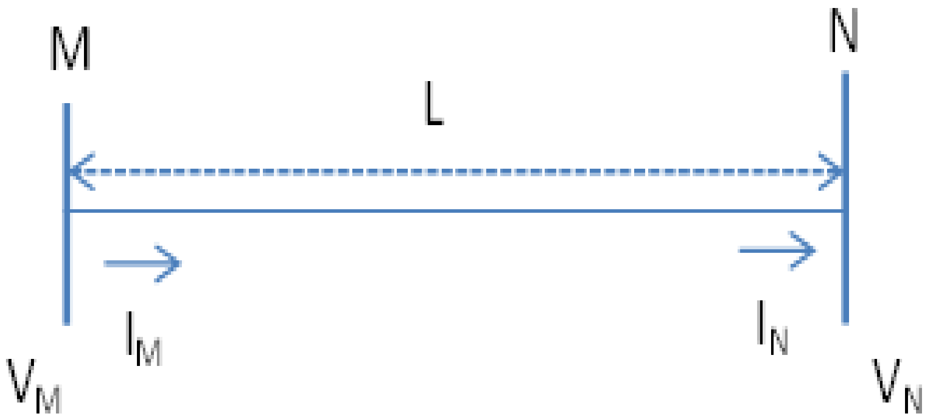
Dual slope bias characteristic

needed.

New Multi-end Differential Protection Capacitance compensation (1/3)

Capacitive current of feeders should be eliminated, especially for overhead lines longer than 50km and cables longer than 10km (typical)

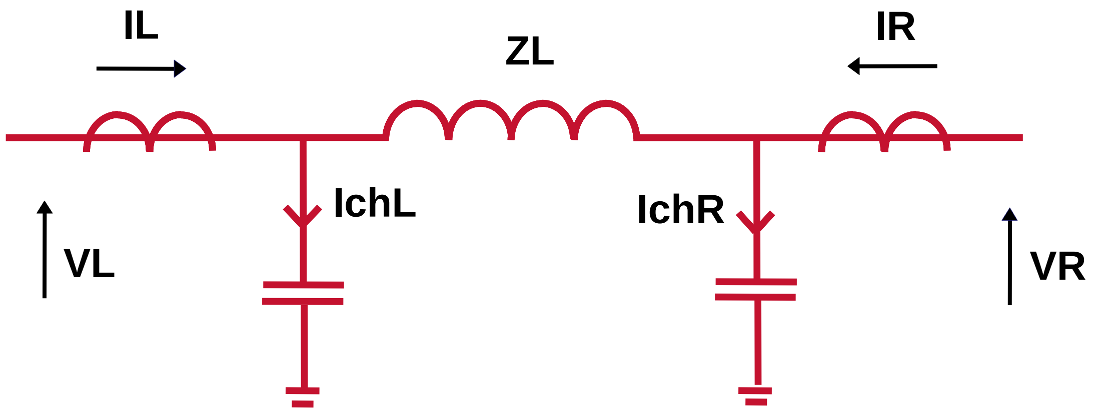
- The objective of capacitive current compensation is to calculate the current at terminal N based on the voltage and current at terminal M
- A distributed parameter line model is used, which is more accurate than the lumped model.



needed.

New Multi-end Differential Protection
Capacitance compensation (2/3)

- Only the impedance and susceptance per unit length are required
- The function has been transposed from the frequency domain to the time domain so that it can be applied to a sample based technique
- High accuracy especially for topologies with long lines. The calculation error is better than 1%.



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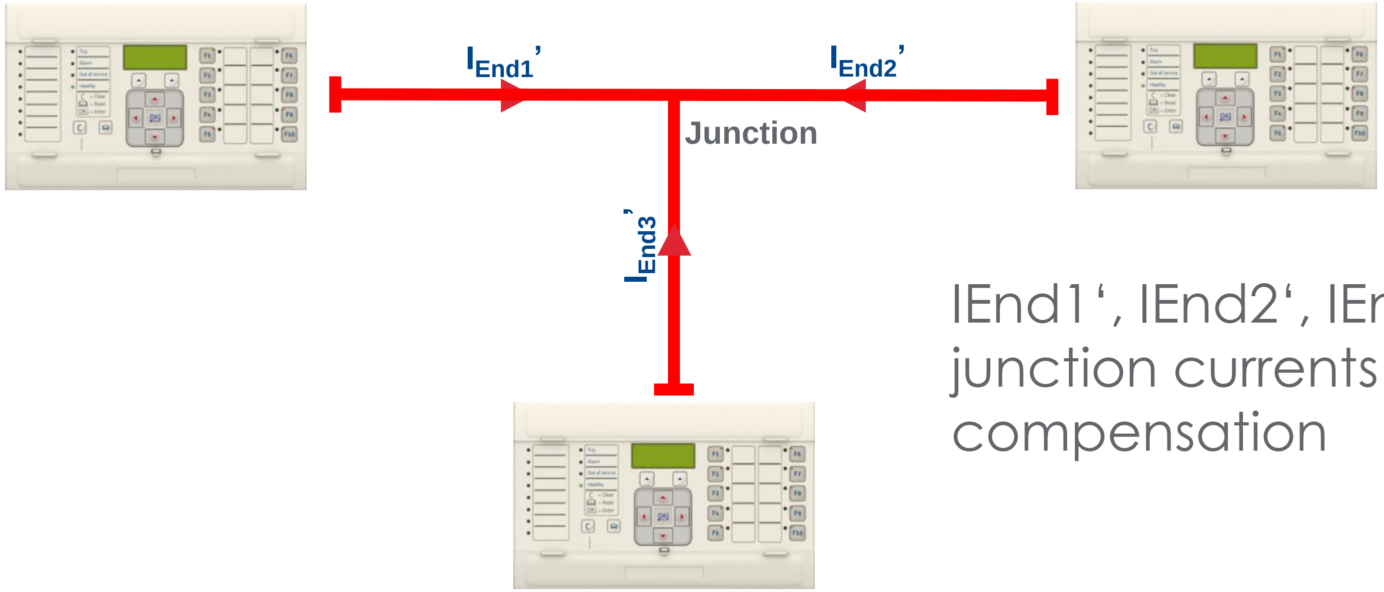
New Multi-end Differential Protection Capacitance compensation (3/3)



IEnd1', IEnd2', IEnd3' = calculated junction currents after charging current compensation

- Based on local measurement of the current & voltage, each relay can remove capacitive charging current from the line end to the junction and calculate the voltage and current at the junction : IEnd1', IEnd2', IEnd3' .
- IEnd1', IEnd2', IEnd3' current (with charging component removed) are sent to remote ends for differential calculation.

needed.

New Multi-end Differential Protection
CT saturation & fault discrimination (1/3)

CT saturation detection works using quantities **Ipos** and **Ineg**.

$$I_{Pos} = \sum_{k \in Pos} i_k$$

Sum of positive samples

$$I_{Neg} = \sum_{k \in Neg} i_k$$

Sum of negative samples

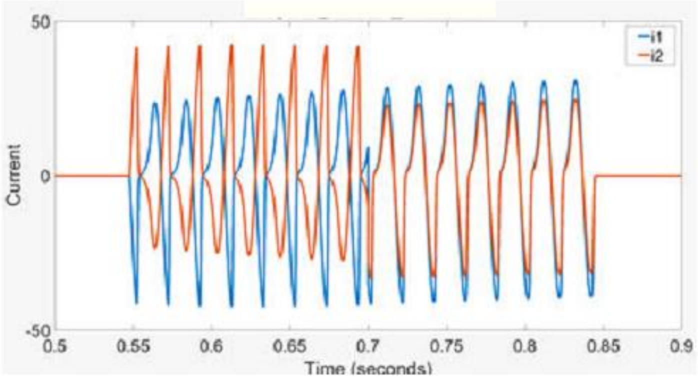
$$\| I_{Pos}(n) + I_{Neg}(n) \| < \| I_{Pos}(n) - I_{Neg}(n) \|$$

External faults

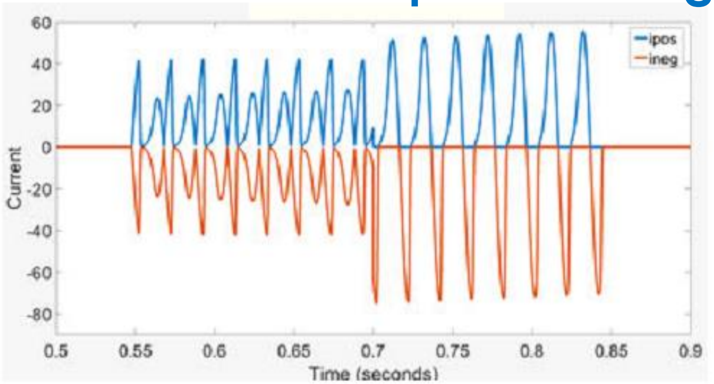
$$\| I_{Pos}(n) + I_{Neg}(n) \| = \| I_{Pos}(n) - I_{Neg}(n) \|$$

Internal faults

Evolving fault



Ipos and Ineg



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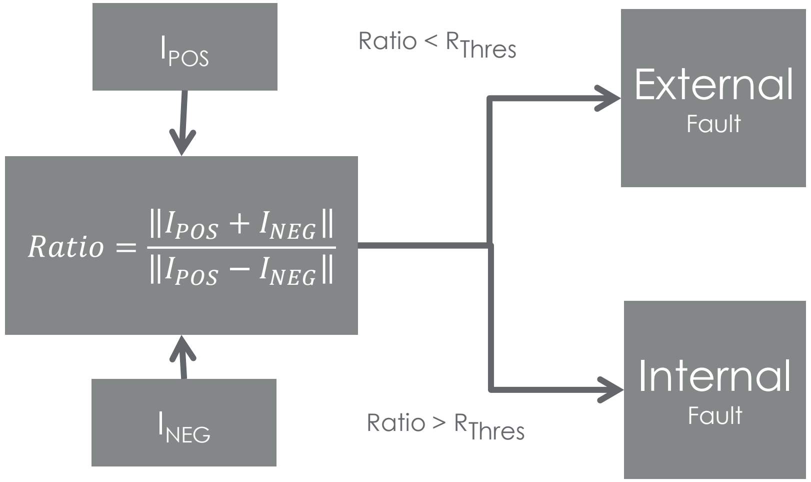
New Multi-end Differential Protection
CT saturation & fault discrimination (2/3)

Logic for fault discrimination

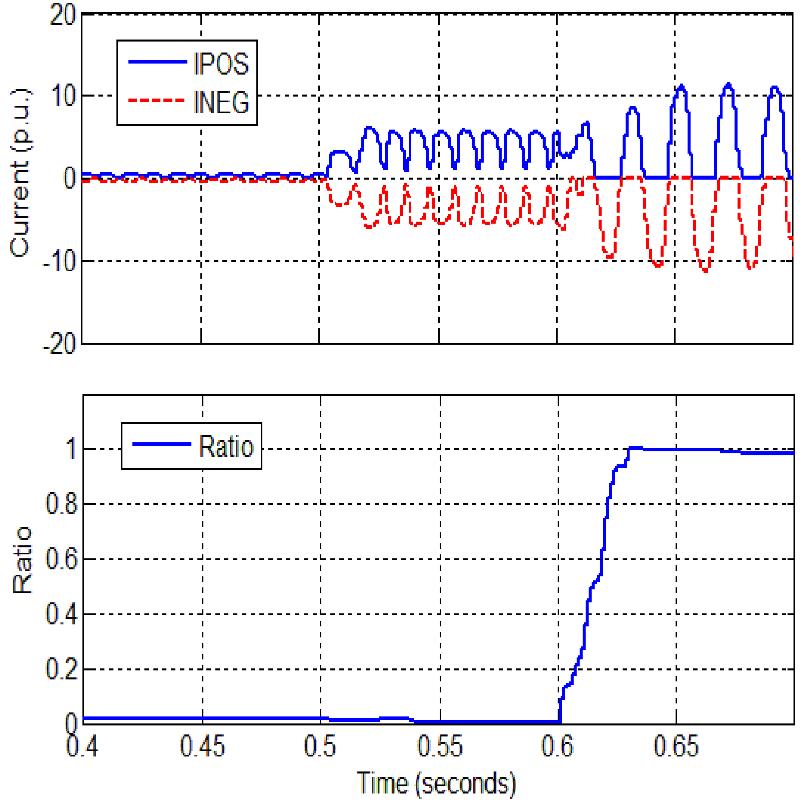


New CT saturation technique reduces CT dimensioning requirements

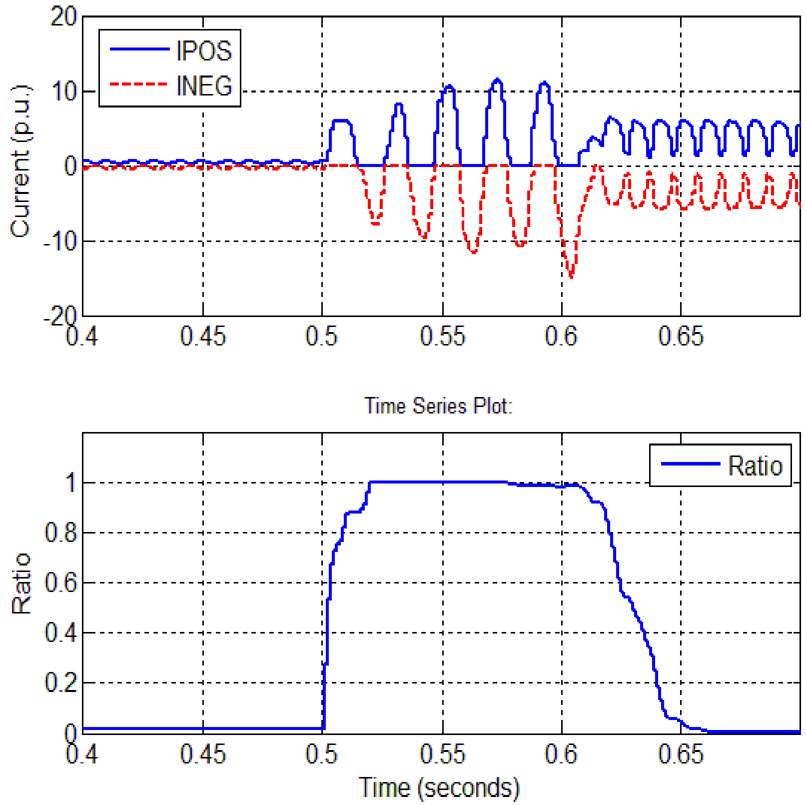
needed.

New Multi-end Differential Protection
CT saturation & fault discrimination (3/3)

IPOS, INEG and Ratio for external to internal (evolving) fault



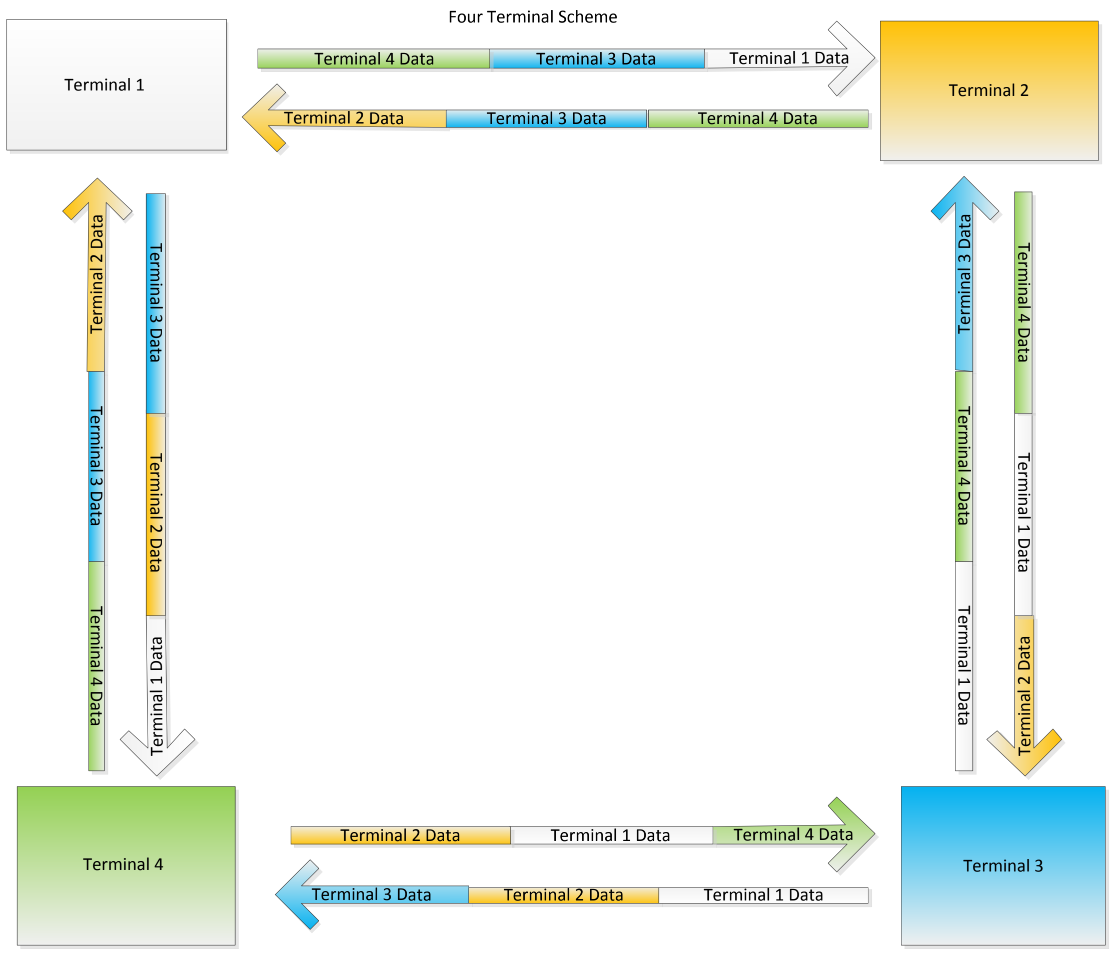
IPOS, INEG and Ratio for internal to external (evolving)



needed.

New Multi-end Differential Protection Communication configuration (1/2)

- Ring configuration, with dual channels
- Possibility to mix channel types
- Protocol: IEEE C37.94, 12 x 64kb/s
- Propagation delays upto 64ms acceptable



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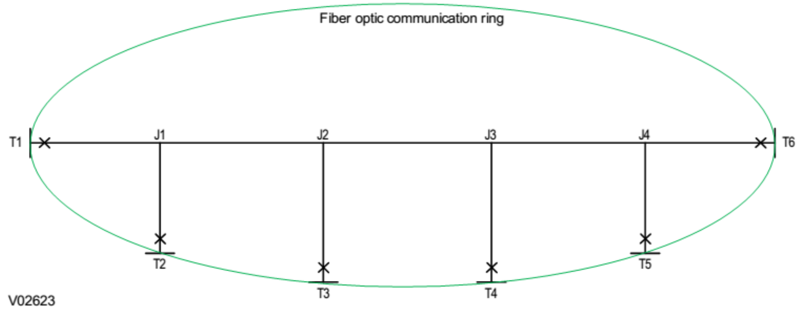
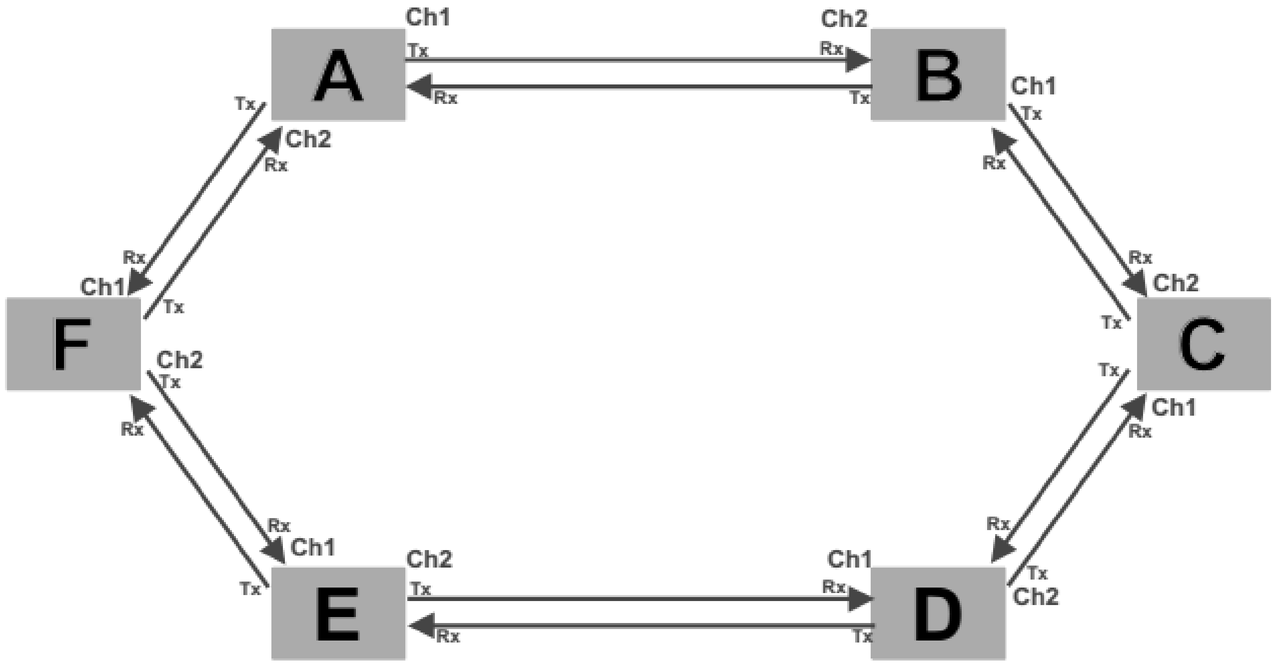
New Multi-end Differential Protection Communication configuration (2/2)

- Upto 6 line ends, thus provision for future expansion
- Ring provides redundancy in case of comms failure





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New Multi-end Differential Protection Scheme reconfiguration

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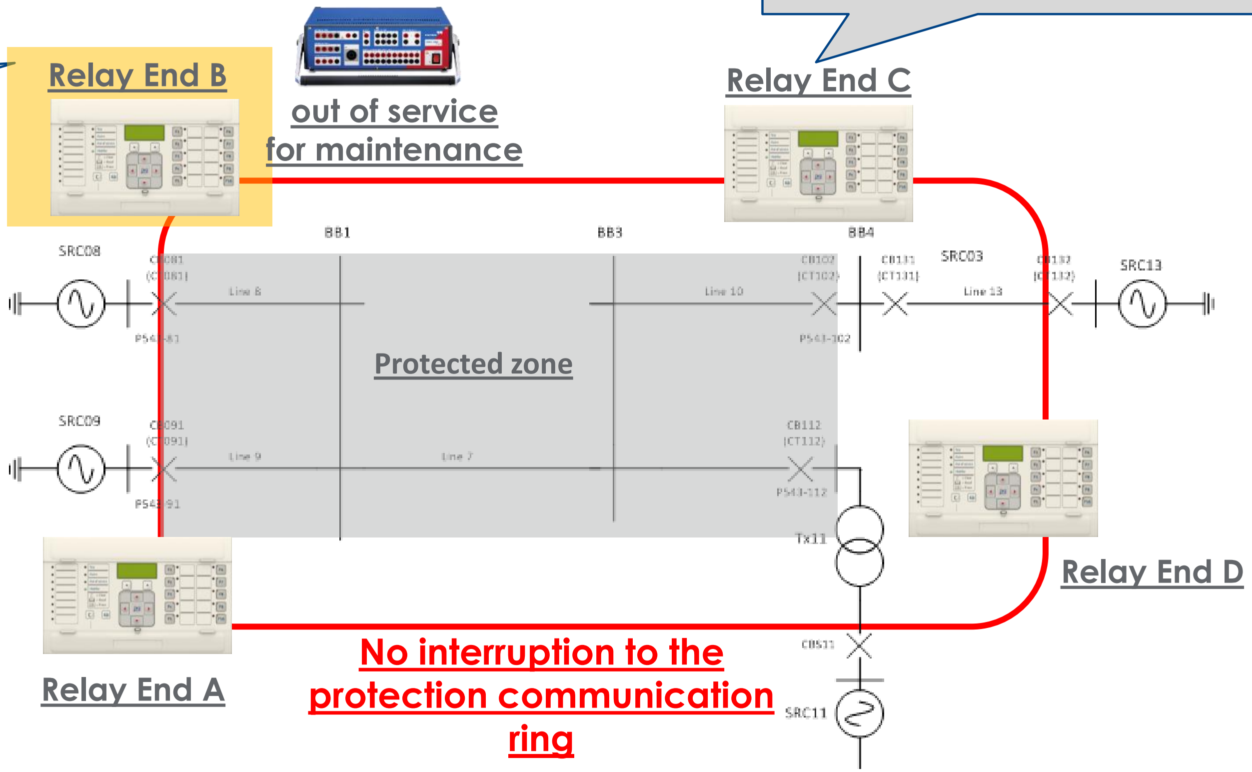
1 Open the CB at End B

2

3

End B Protection out of service for maintenance, BUT communication continues



Any relay
(Reconfiguration command can be sent from any relay,
The relay will get 'reconfiguration confirmation')

GE