Cross-differential protection - what it is and why we need it

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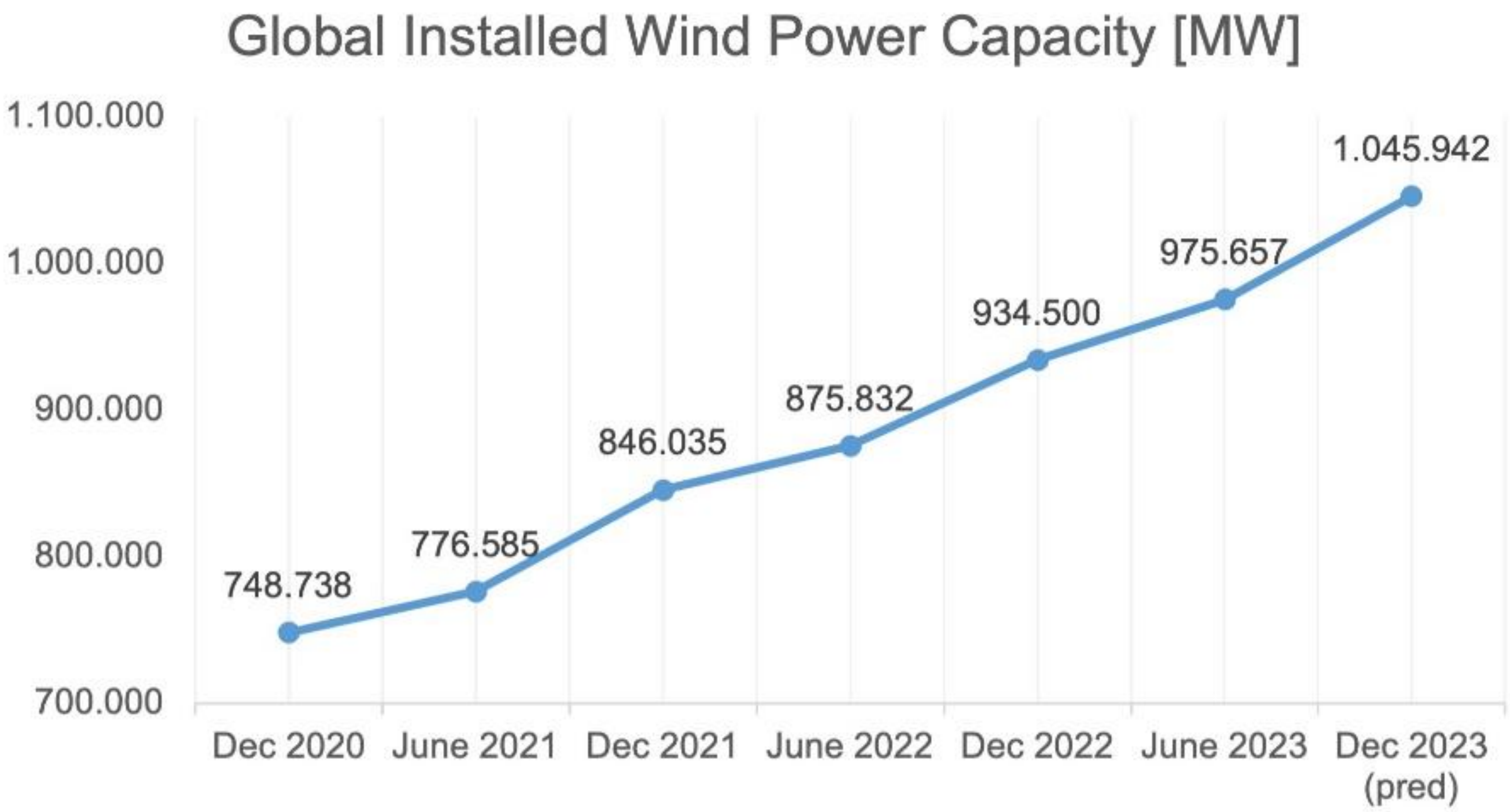
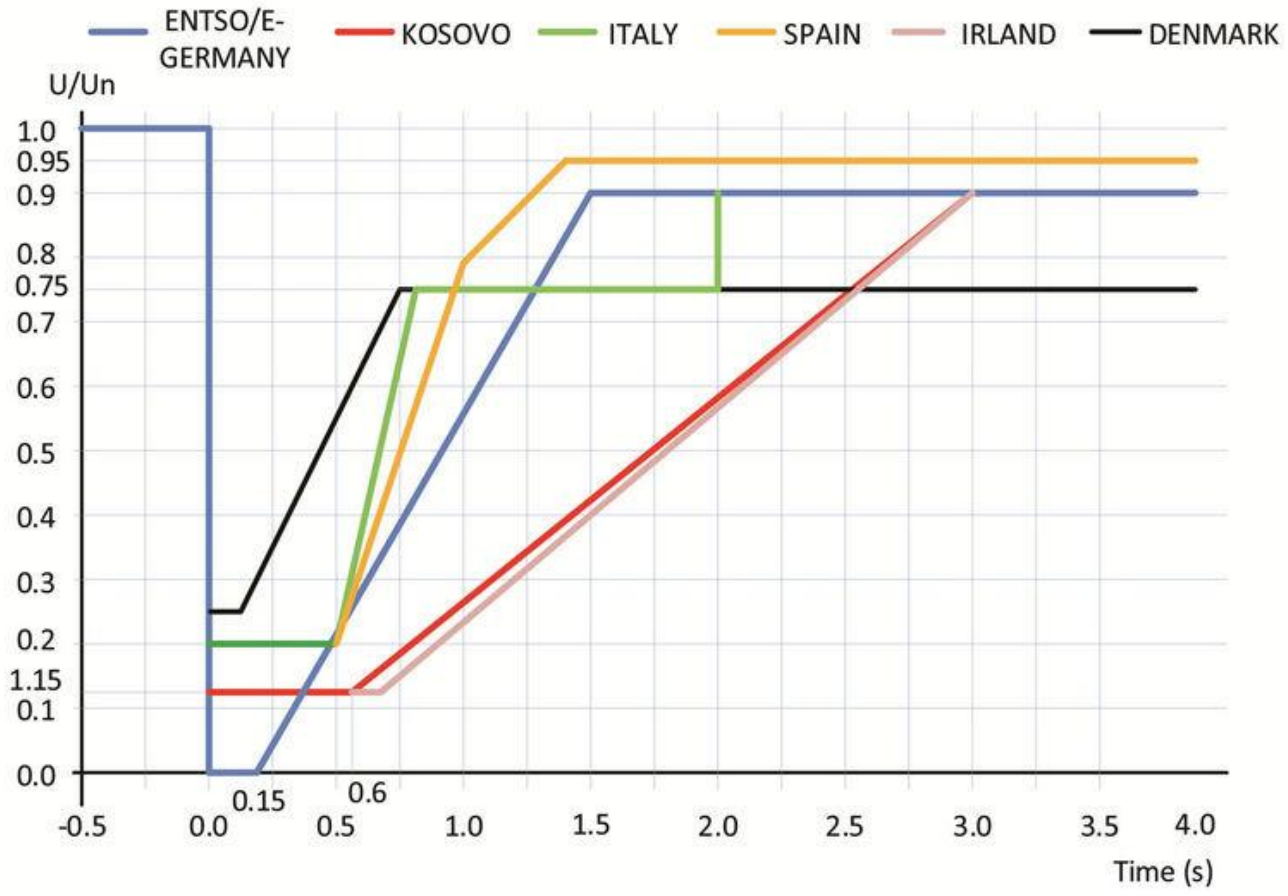
Questions

- What are we doing?
- Why are we doing it?
- How are we doing it?

Changing industry

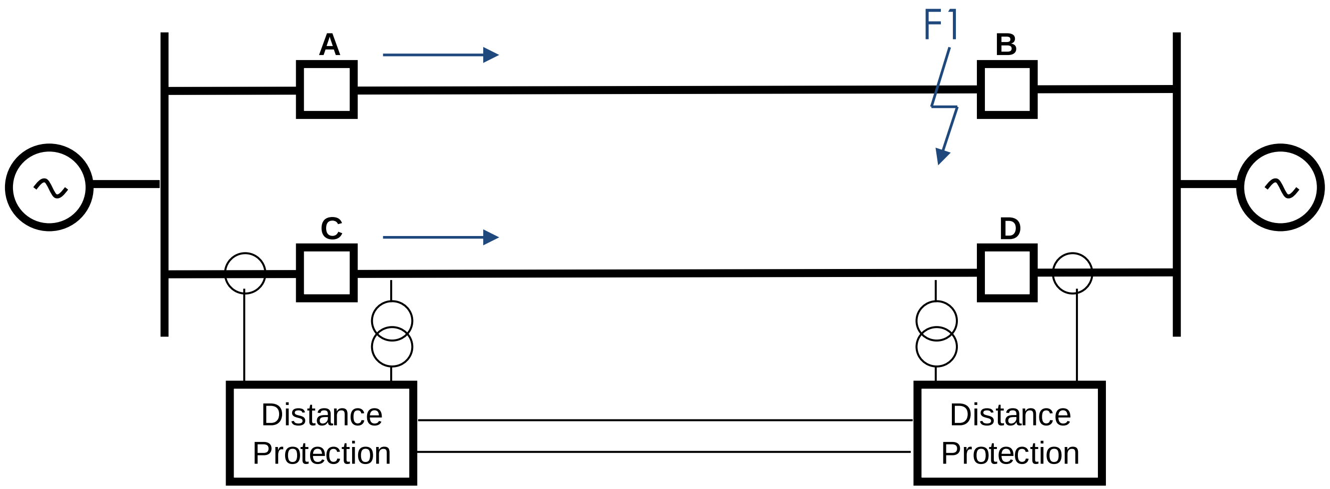


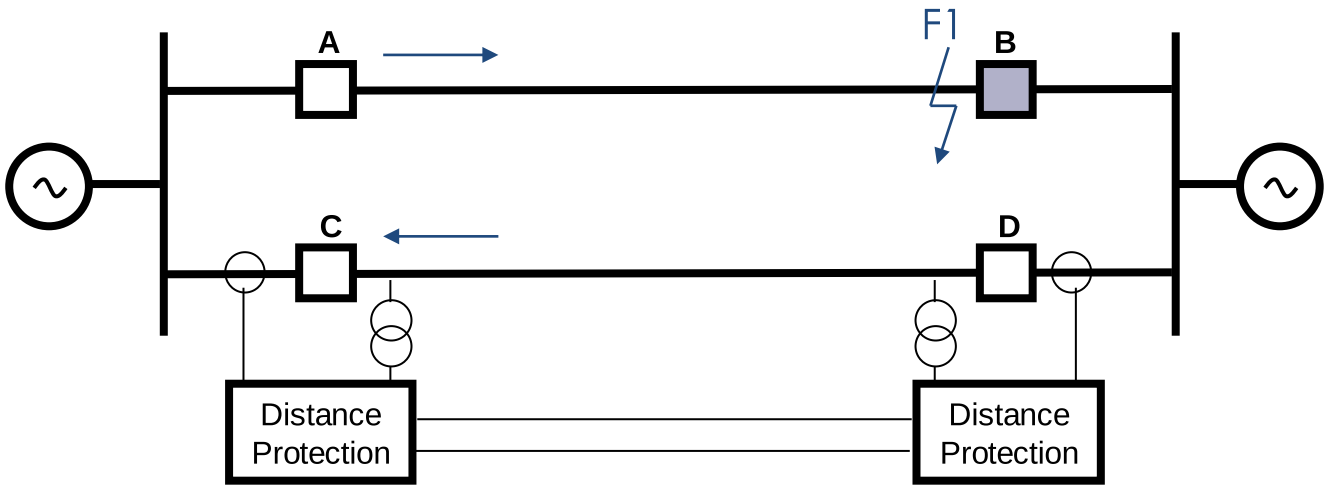
Changing industry



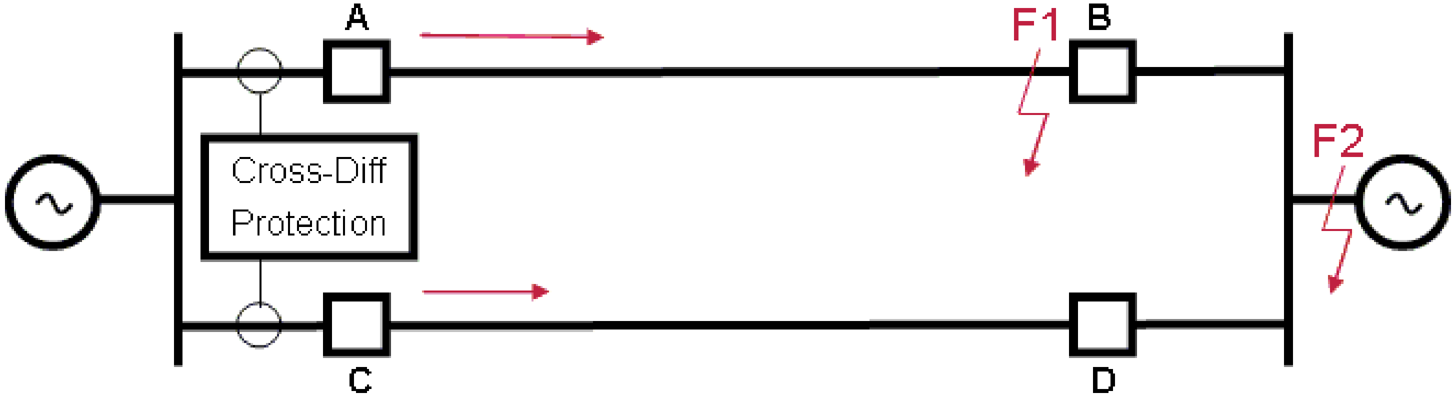
Double circuit lines

Distance protection





Cross-differential protection

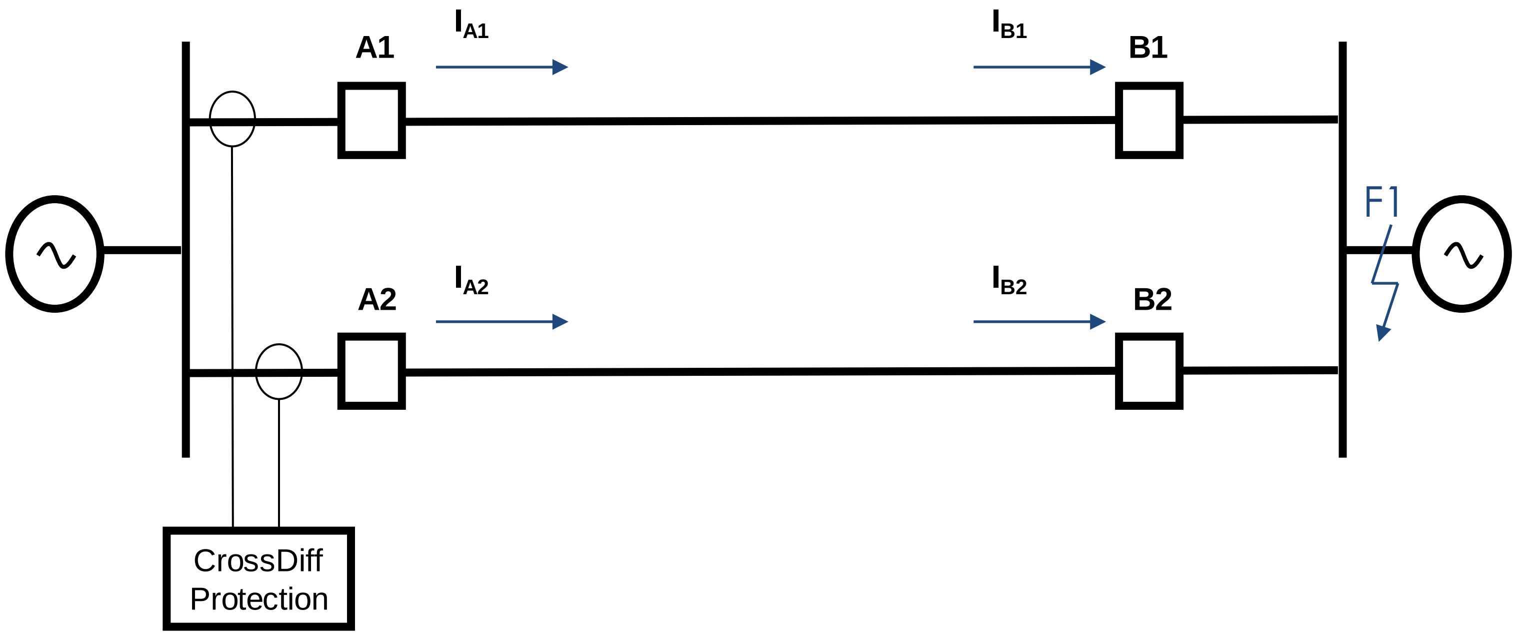


$$|I_1| - |I_2| > I_{op} \rightarrow \text{Trip Line1}$$

$$|I_2| - |I_1| > I_{op} \rightarrow \text{Trip Line2}$$

Example Parallel Line System - load

Example Parallel Line System – external fault



System analysis 95%

CT A

I L1 prim.:	1.7085 kA	∠	-71.05 °
I L2 prim.:	86.597 A	∠	82.49 °
I L3 prim.:	86.570 A	∠	-37.45 °

CT A2

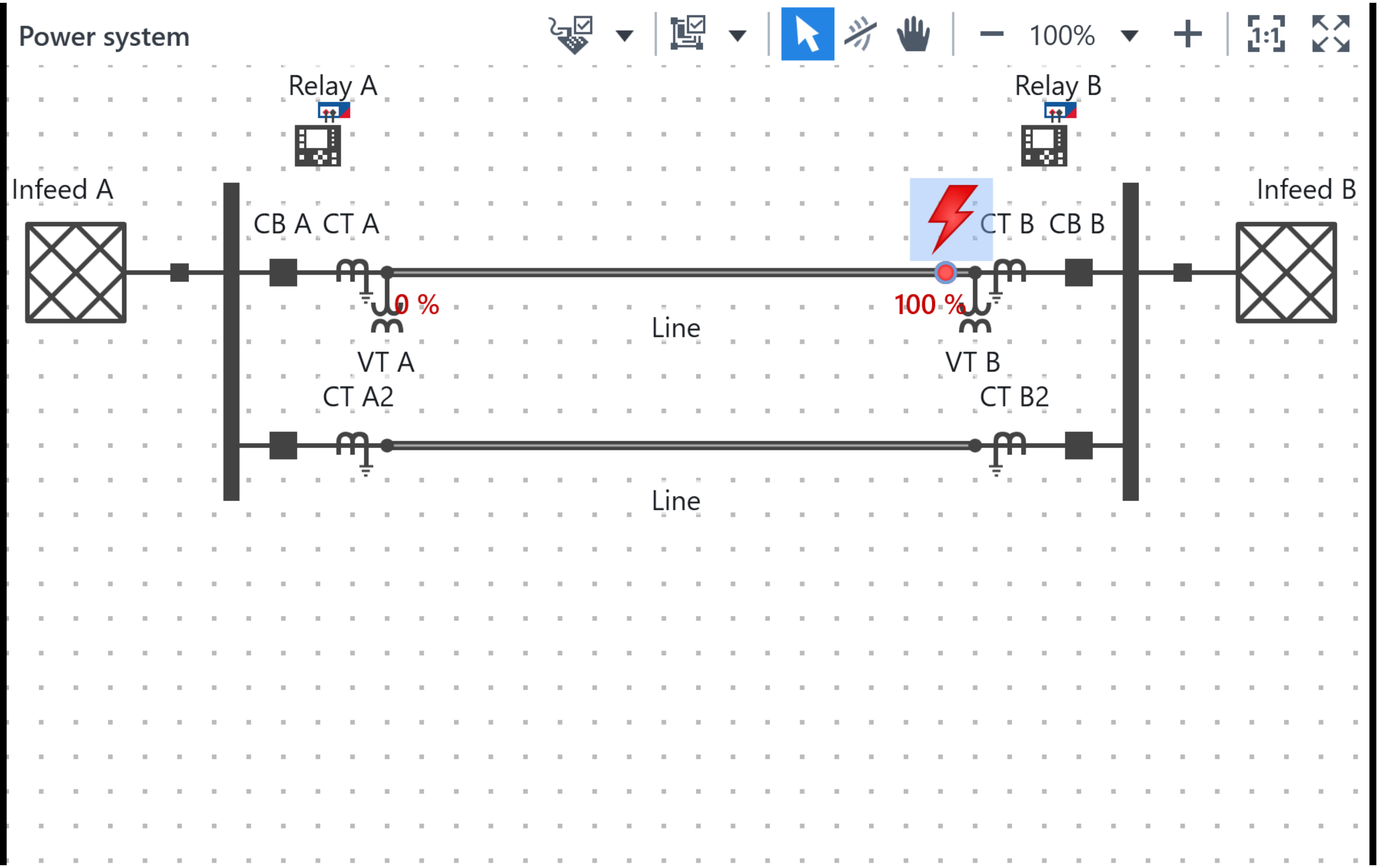
I L1 prim.:	1.4573 kA	∠	-71.54 °
I L2 prim.:	86.544 A	∠	82.51 °
I L3 prim.:	86.568 A	∠	-37.54 °

CT B

I L1 prim.:	3.3242 kA	∠	-66.64 °
I L2 prim.:	86.597 A	∠	-97.51 °
I L3 prim.:	86.570 A	∠	142.55 °

CT B2

I L1 prim.:	1.4573 kA	∠	108.46 °
I L2 prim.:	86.544 A	∠	-97.49 °
I L3 prim.:	86.568 A	∠	142.46 °



System analysis 97%

CT A

I L1 prim.:	1.6610 kA	∠	-71.12 °
I L2 prim.:	86.600 A	∠	82.49 °
I L3 prim.:	86.570 A	∠	-37.45 °

CT A2

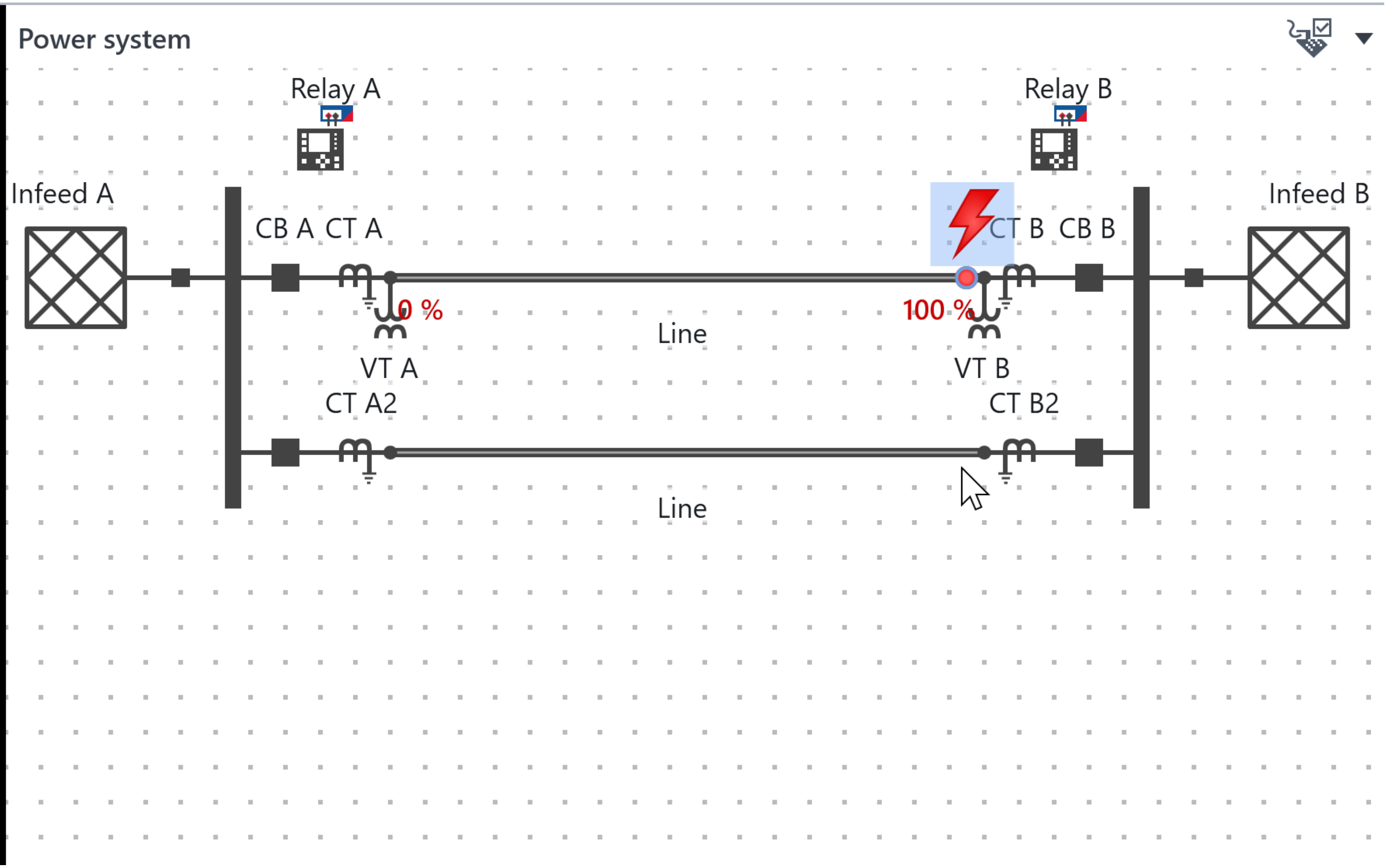
I L1 prim.:	1.5096 kA	∠	-71.41 °
I L2 prim.:	86.542 A	∠	82.51 °
I L3 prim.:	86.568 A	∠	-37.54 °

CT B

I L1 prim.:	3.3895 kA	∠	-66.67 °
I L2 prim.:	86.600 A	∠	-97.51 °
I L3 prim.:	86.570 A	∠	142.55 °

CT B2

I L1 prim.:	1.5096 kA	∠	108.59 °
I L2 prim.:	86.542 A	∠	-97.49 °
I L3 prim.:	86.568 A	∠	142.46 °



System analysis 99%

CT A

I L1 prim.:	1.6134 kA	∠	-71.21 °
I L2 prim.:	86.602 A	∠	82.49 °
I L3 prim.:	86.571 A	∠	-37.45 °

CT A2

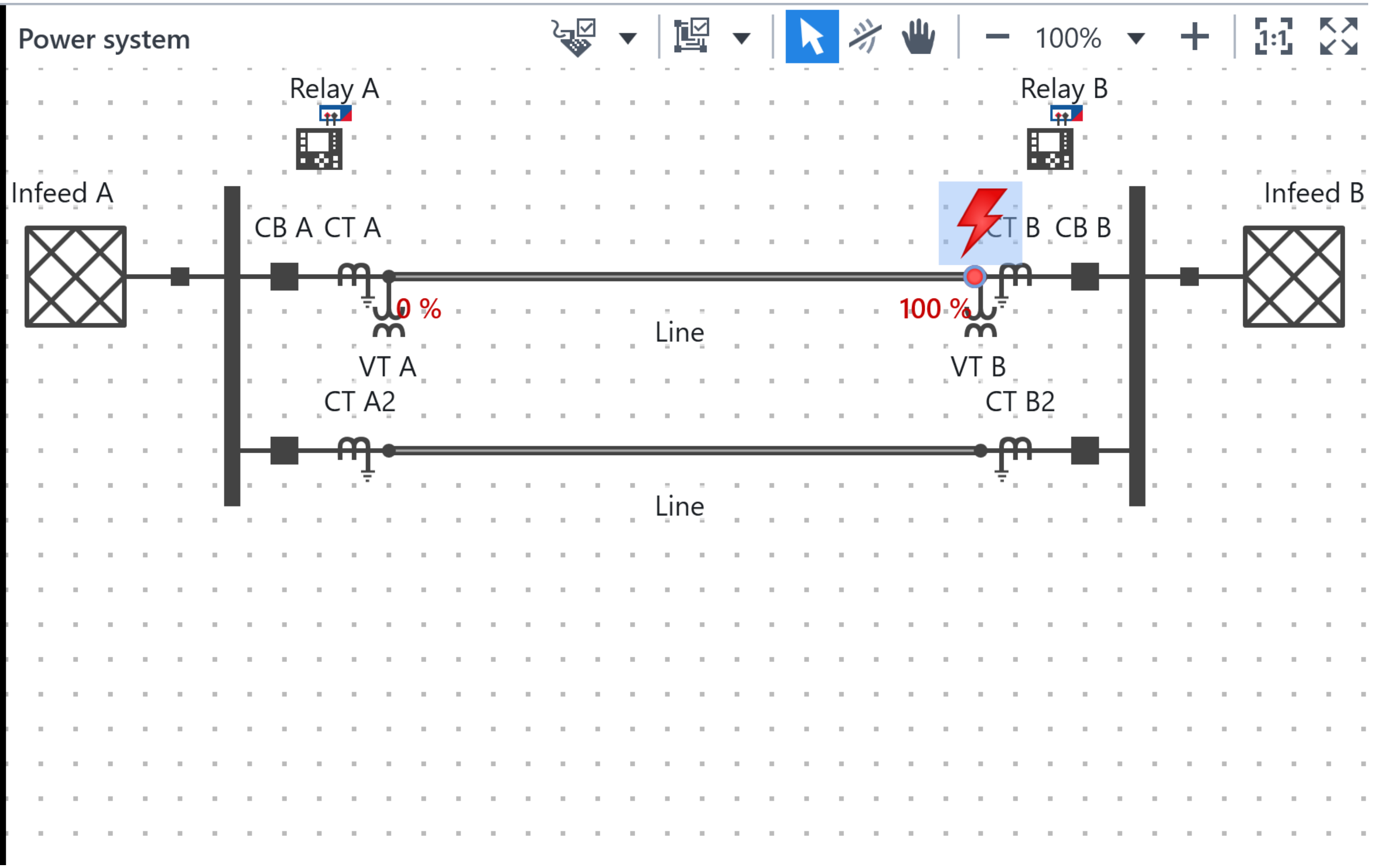
I L1 prim.:	1.5627 kA	∠	-71.30 °
I L2 prim.:	86.539 A	∠	82.51 °
I L3 prim.:	86.567 A	∠	-37.54 °

CT B

I L1 prim.:	3.4561 kA	∠	-66.69 °
I L2 prim.:	86.602 A	∠	-97.51 °
I L3 prim.:	86.571 A	∠	142.55 °

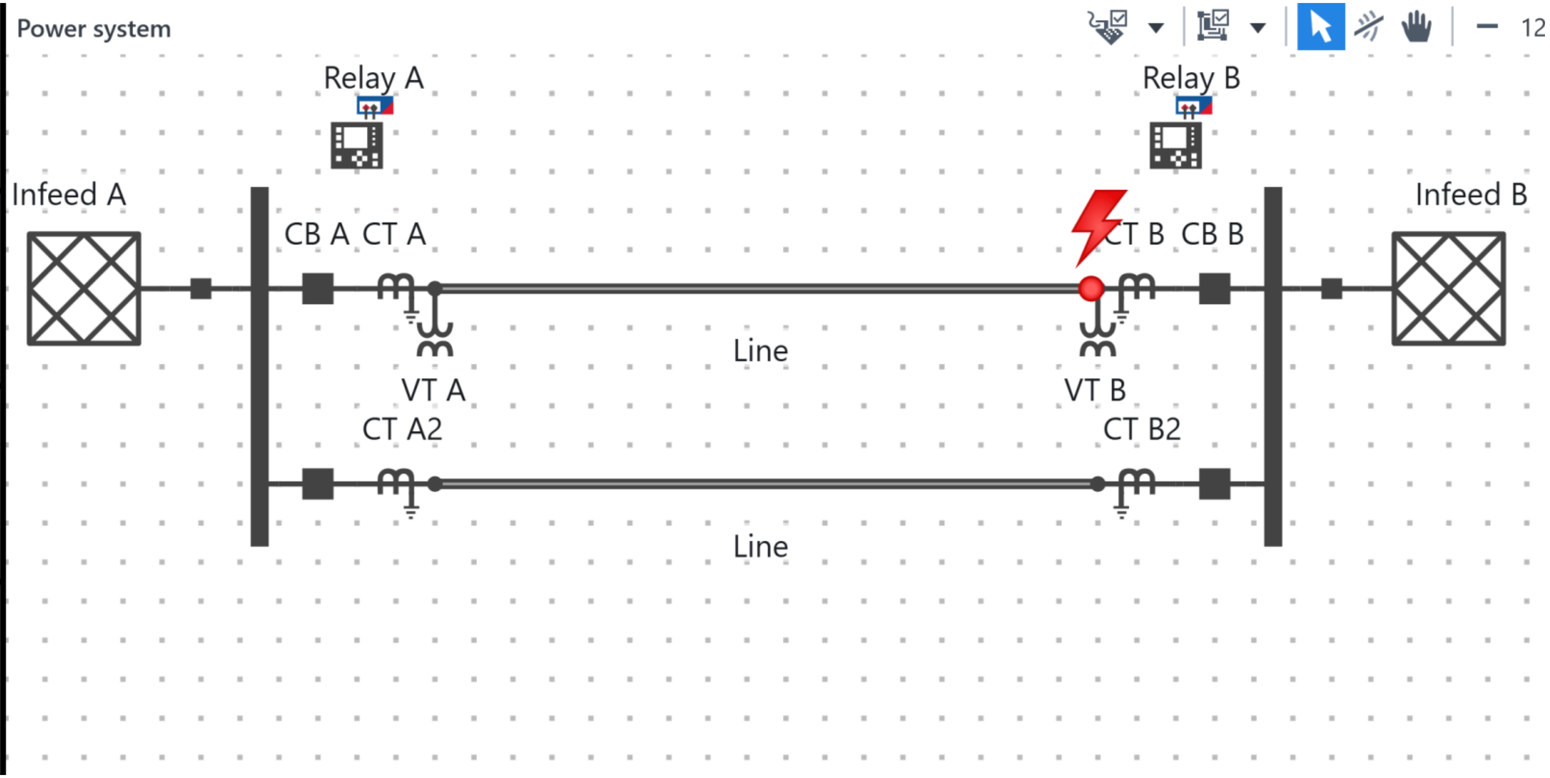
CT B2

I L1 prim.:	1.5627 kA	∠	108.70 °
I L2 prim.:	86.539 A	∠	-97.49 °
I L3 prim.:	86.567 A	∠	142.46 °

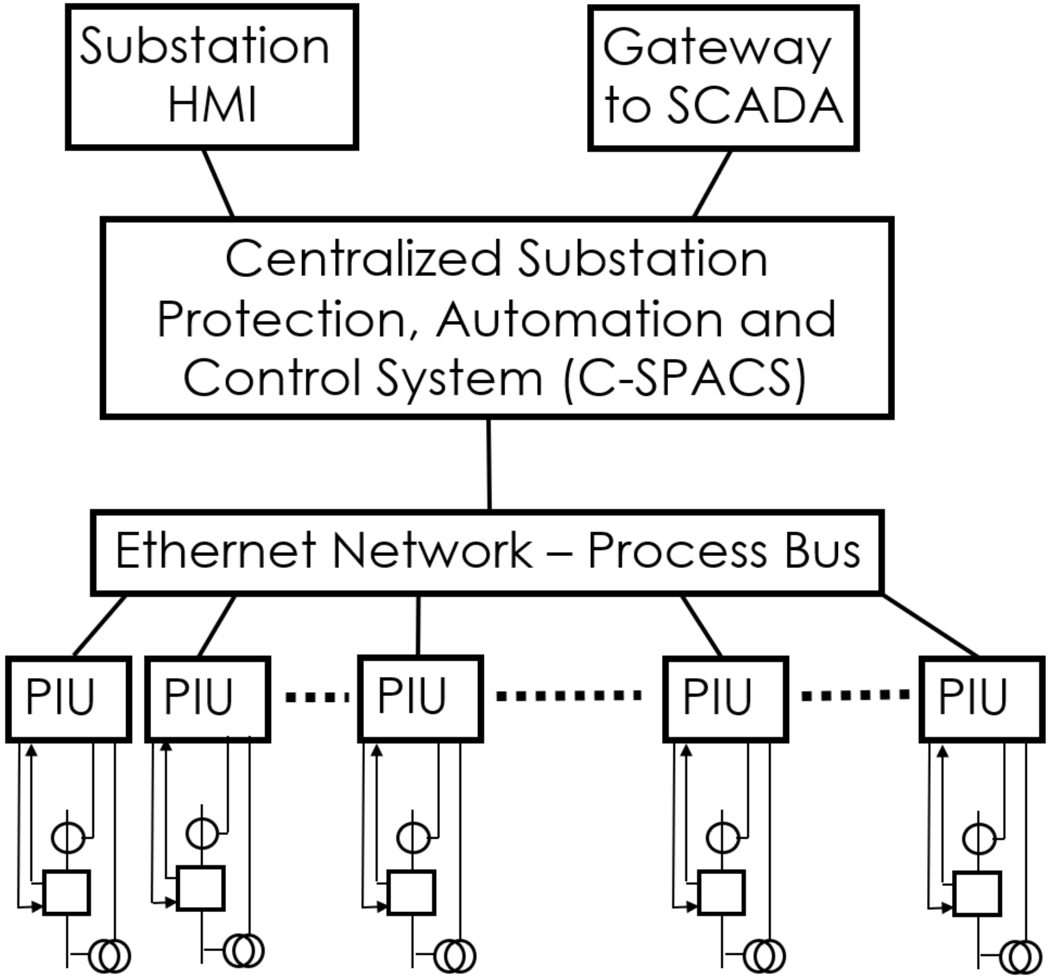


System analysis 99% with IBR

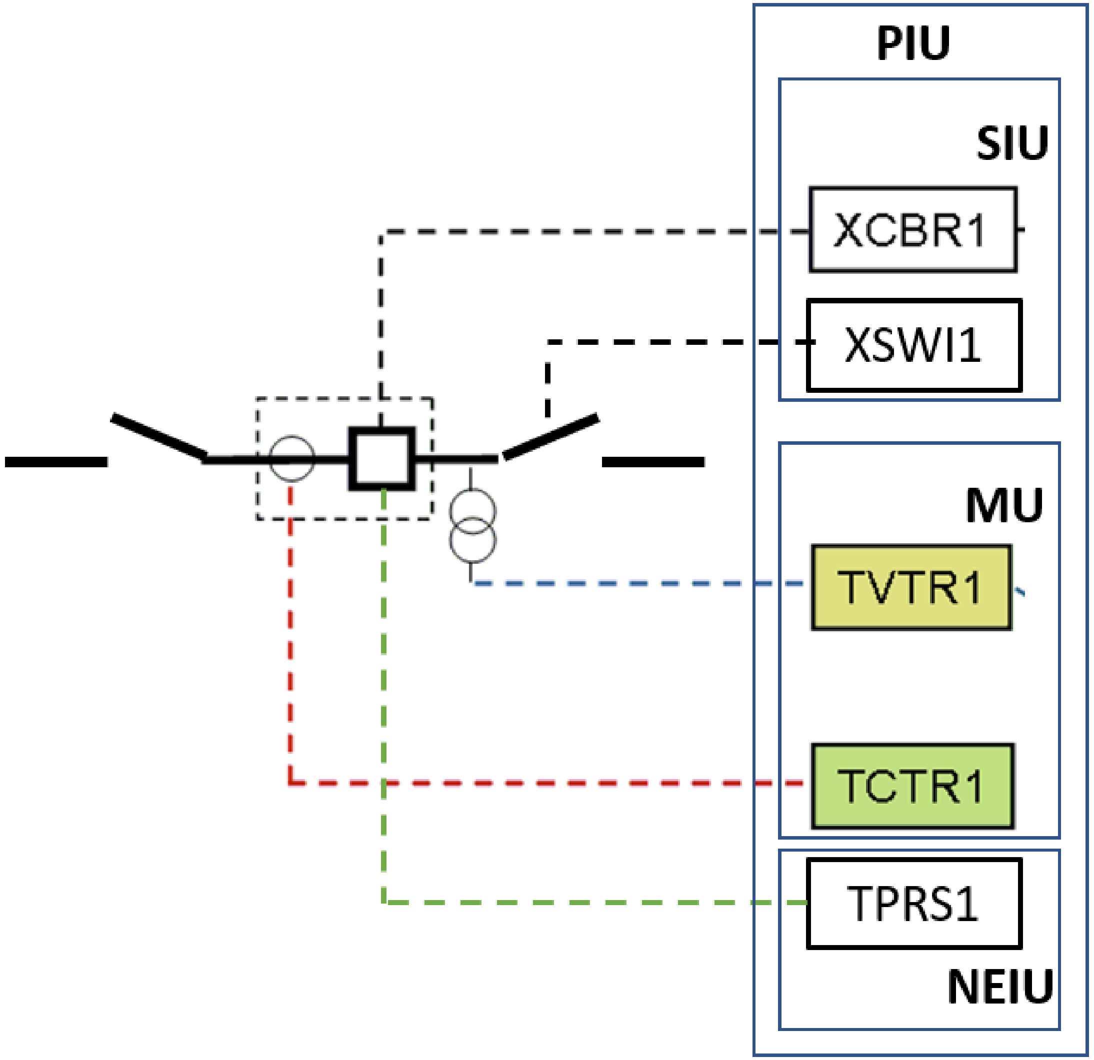
CT A	I L1 prim.:	1.6039 kA	-70.06 °
	I L2 prim.:	4.5267 A	82.51 °
	I L3 prim.:	4.5263 A	-37.48 °
CT A2	I L1 prim.:	1.5716 kA	-70.07 °
	I L2 prim.:	4.5262 A	82.49 °
	I L3 prim.:	4.5267 A	-37.52 °
CT B	I L1 prim.:	1.6346 kA	-69.74 °
	I L2 prim.:	4.5267 A	-97.49 °
	I L3 prim.:	4.5263 A	142.52 °
CT B2	I L1 prim.:	1.5716 kA	109.93 °
	I L2 prim.:	4.5262 A	-97.51 °
	I L3 prim.:	4.5267 A	142.48 °



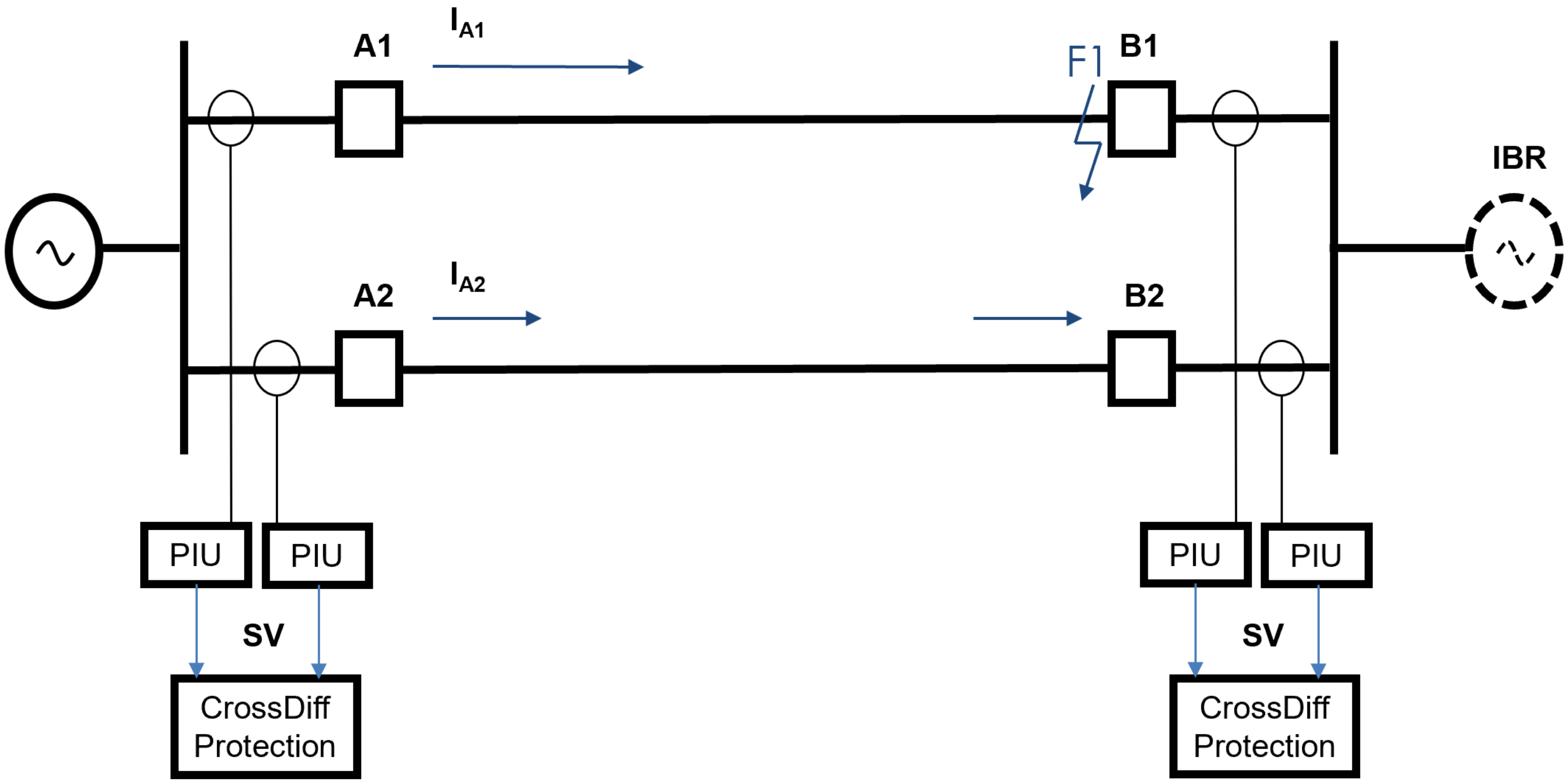
CSPACS


Substation HMI
Gateway to SCADA
Centralized Substation Protection, Automation and Control System (C-SPACS)
Ethernet Network – Process Bus
PIU
PIU
PIU
PIU
PIU

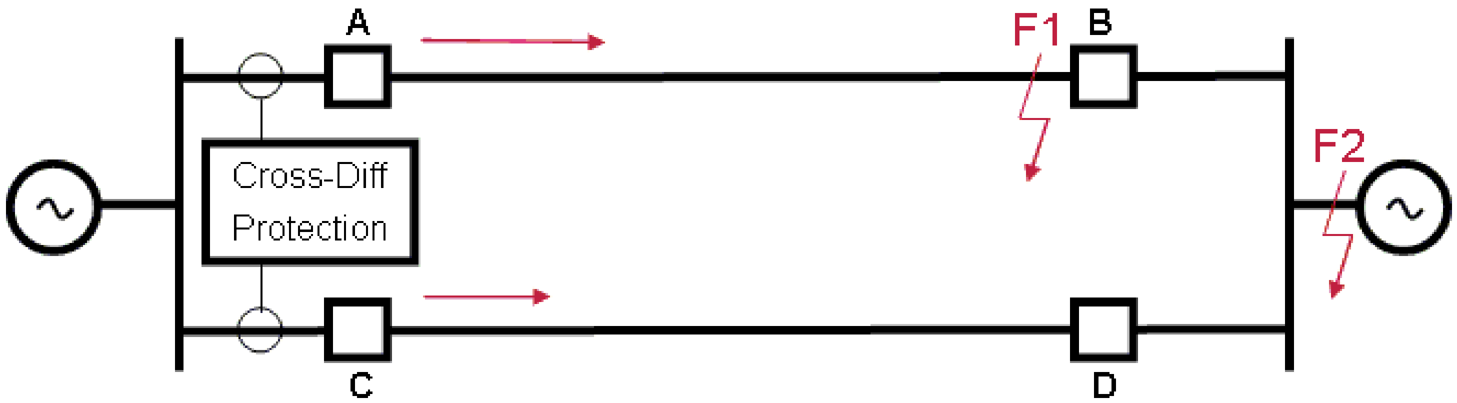
Process Interface Unit (PIU)



System analysis



Cross-differential protection implementations



Traditional

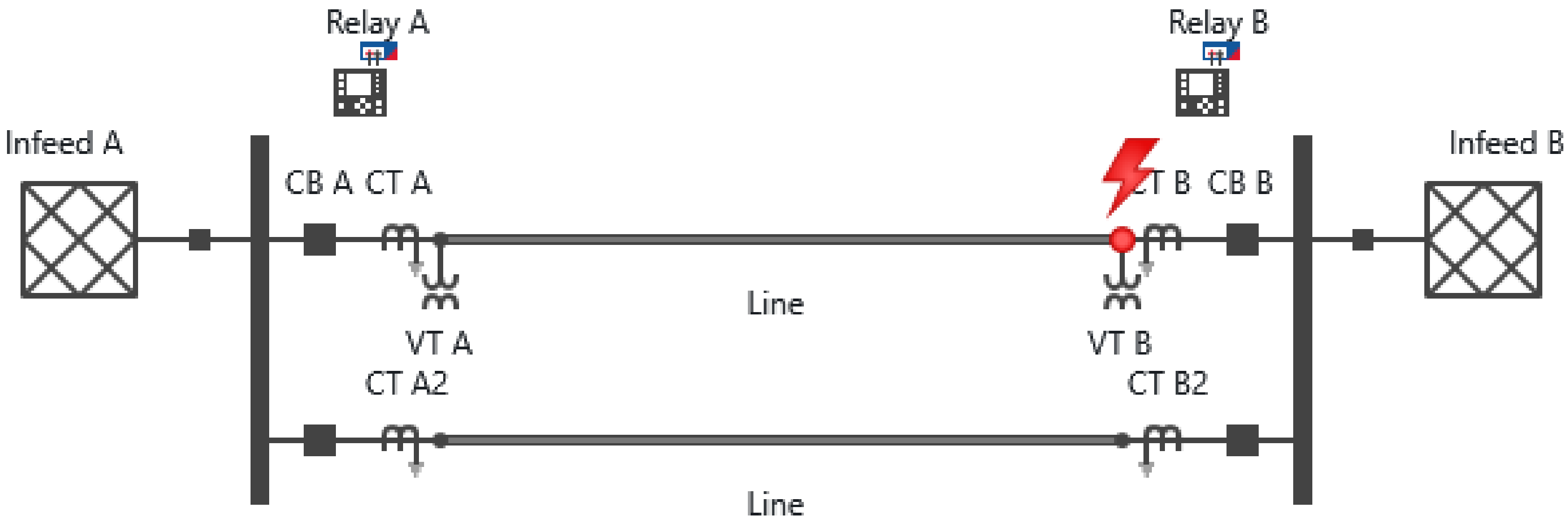
$$|I_1| - |I_2| > I_{op}$$ → Trip Line1

$$|I_2| - |I_1| > I_{op}$$ → Trip Line2

Other methods:

- Superimposed components
- Phasors
- Sampled values

Testing



Relay A
Relay B
Infeed A
Infeed B
CB A
CT A
CT B
CB B
Line
VT A
VT B
CT A2
CT B2
Line

Conclusions

- Cross-differential protection represents a significant advancement in the protection of double circuit transmission lines, offering superior sensitivity and selectivity in detecting internal faults.
- By using currents from both circuits into its operating principle, it provides a robust solution to the challenges posed by the unique characteristics of these transmission lines.
- Cross differential protection requires careful consideration of technical and engineering factors, but its benefits in enhancing system reliability and safety are undeniable.