Three Terminal Line Application of Distance and Differential Relays in the Entergy System

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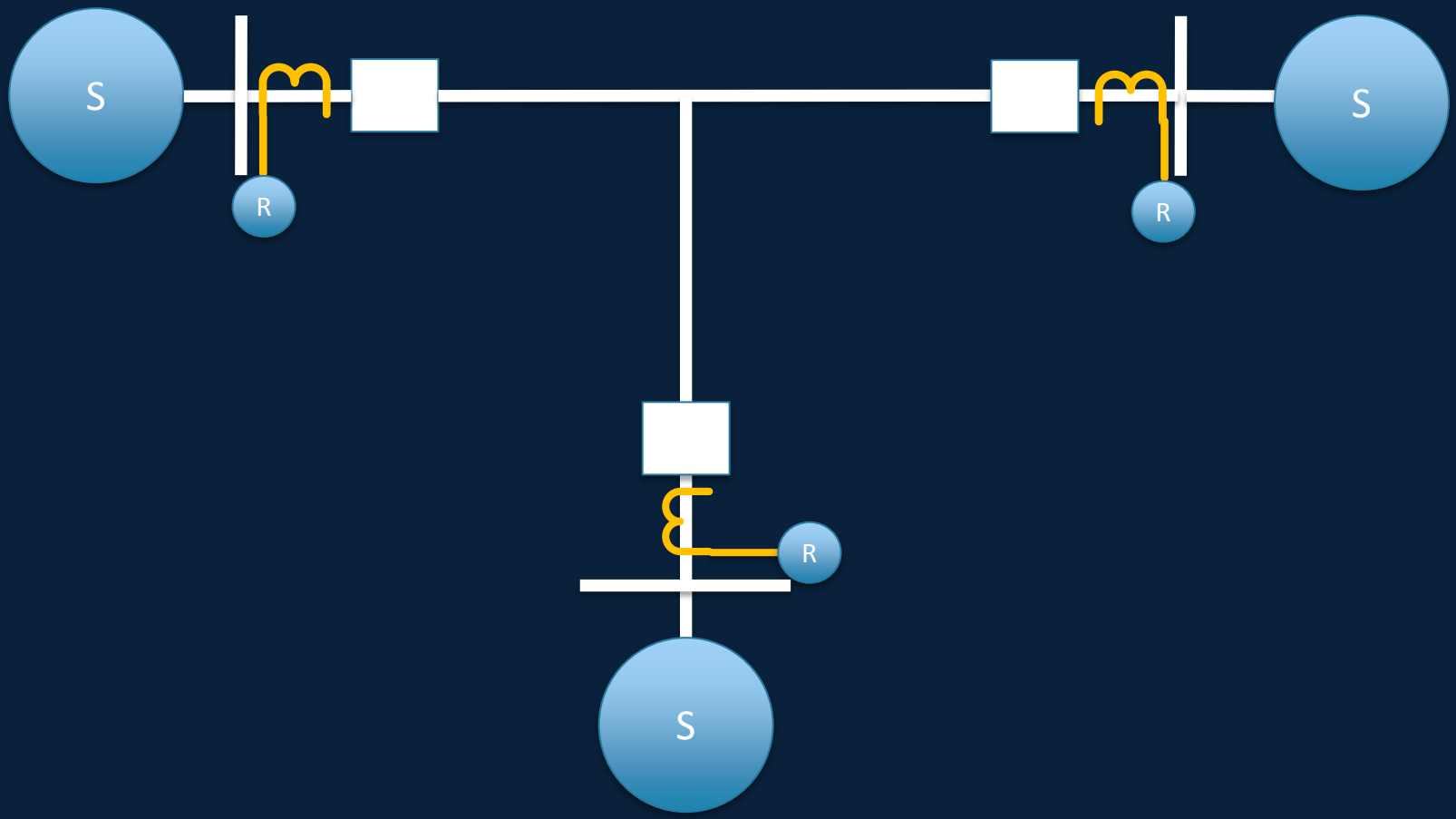
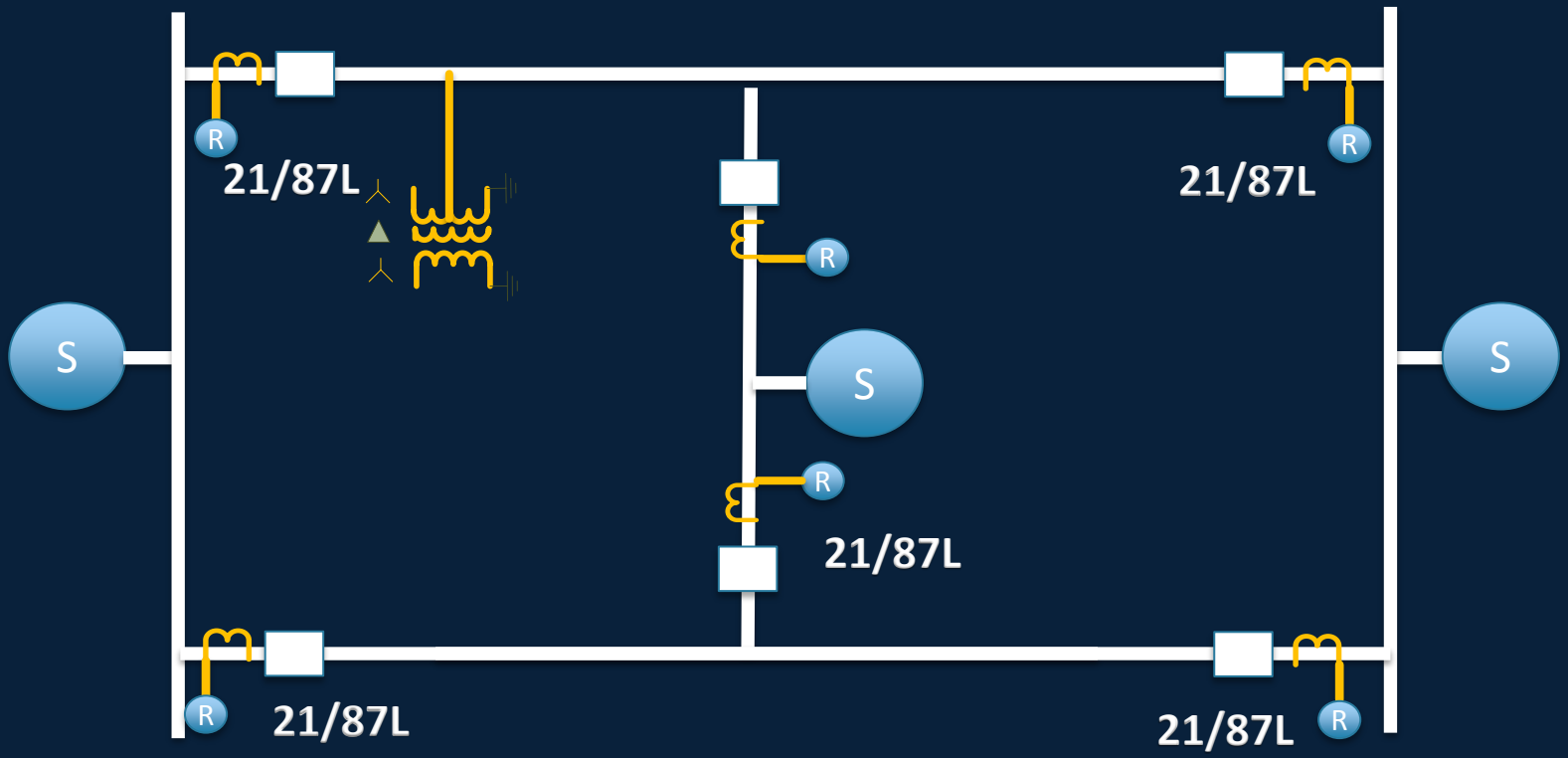
Outline

- Definition of Terminals
- Project Background
- Three Terminal Line Protection Schemes
- Apparent Impedance
- Distance Relay Settings
- Communications
  - DUTT
  - POTT

Types of Lines



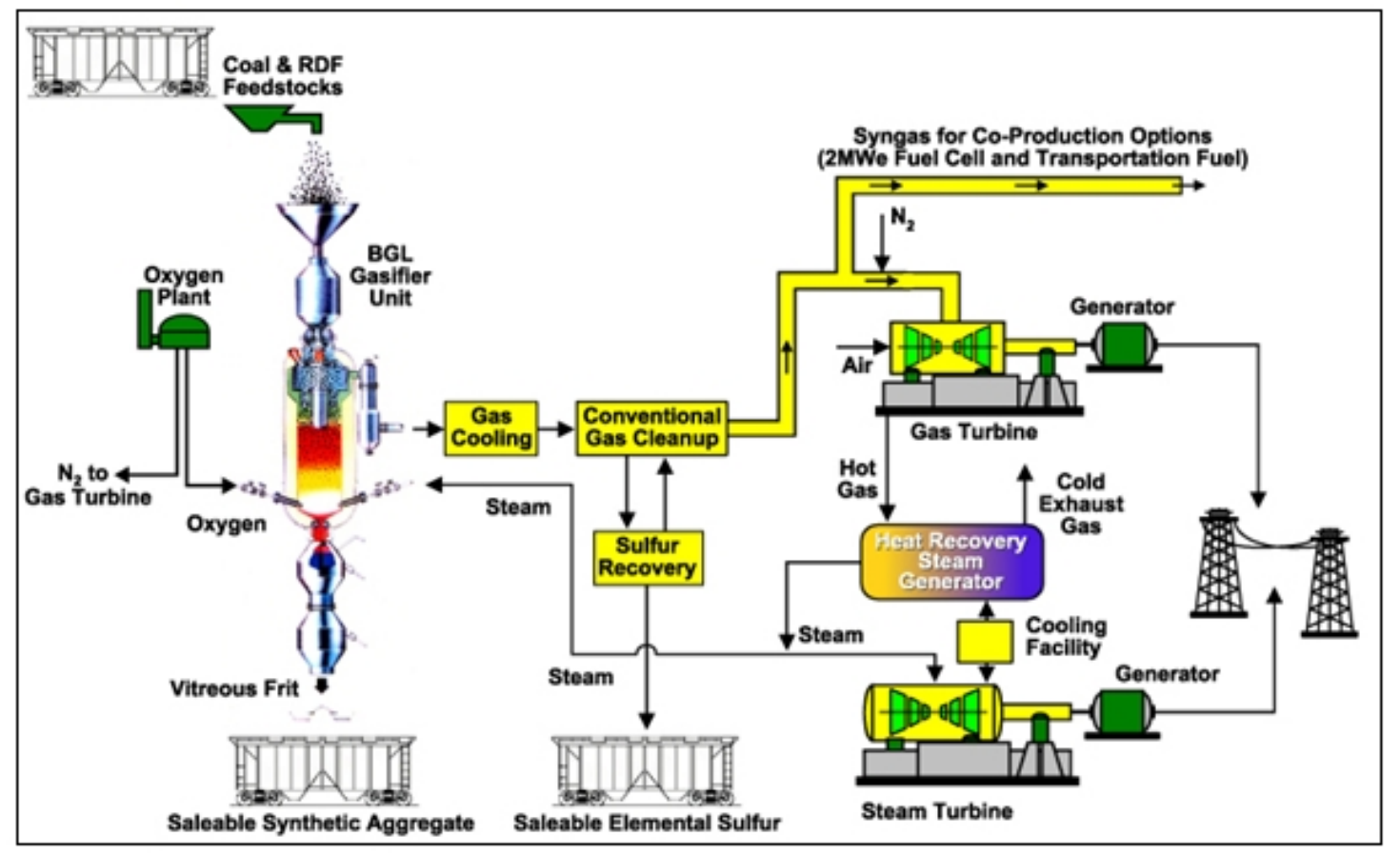
Complex Three Terminal Lines



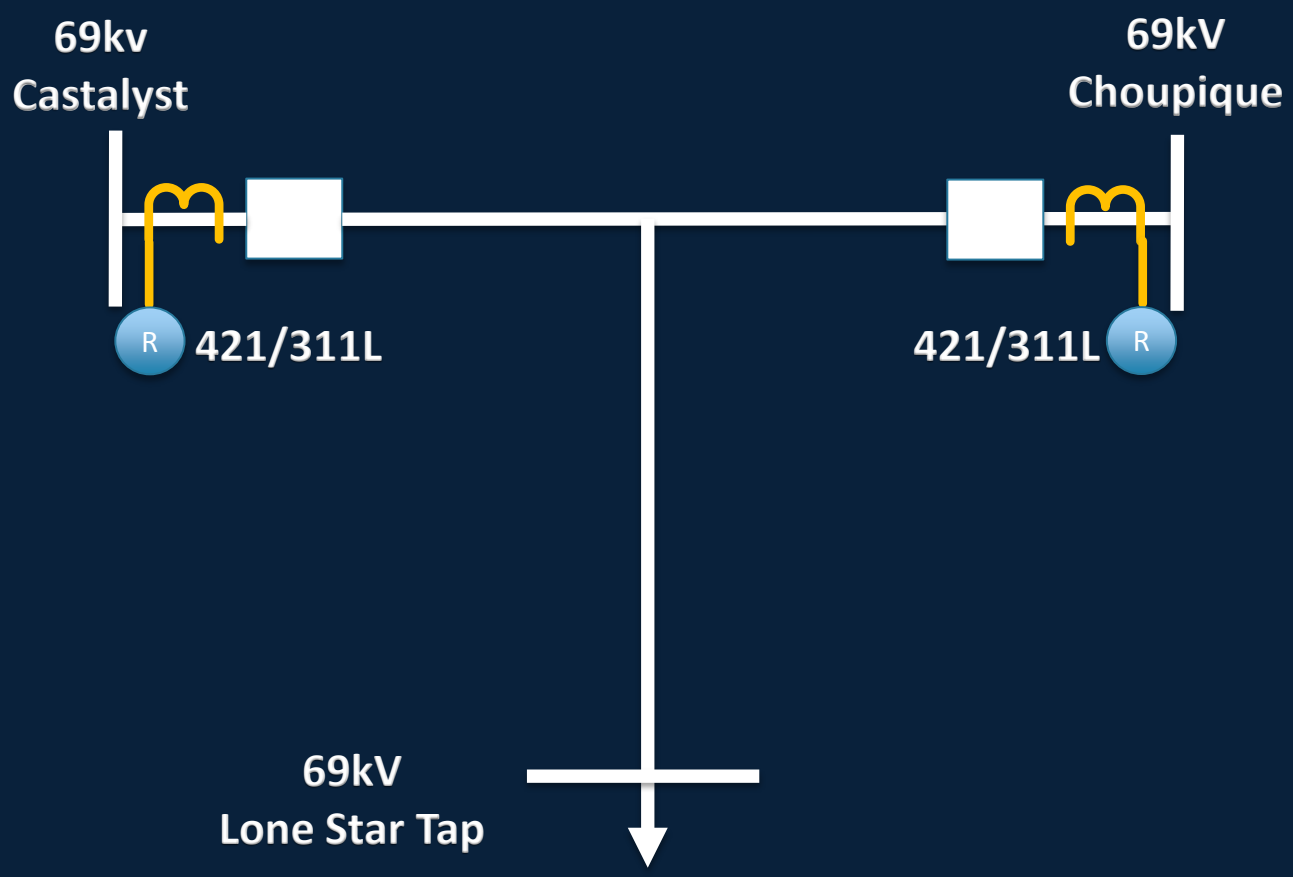
Project Background

- Customer requested interconnection agreement for new generator.
- Customer's facility operates two high temperature rotary kilns to process petroleum coke.
- Exhausts of the rotary kilns are combined and exit to atmosphere through a refractory lined stack at temperatures ranging from 1800°F to 2100°F.
- Proposed project would capture lost energy and co-generate electricity for use at the facility and for sale to Entergy.
- A condensing steam-driven turbine generator would produce 36.4 MW of electricity.

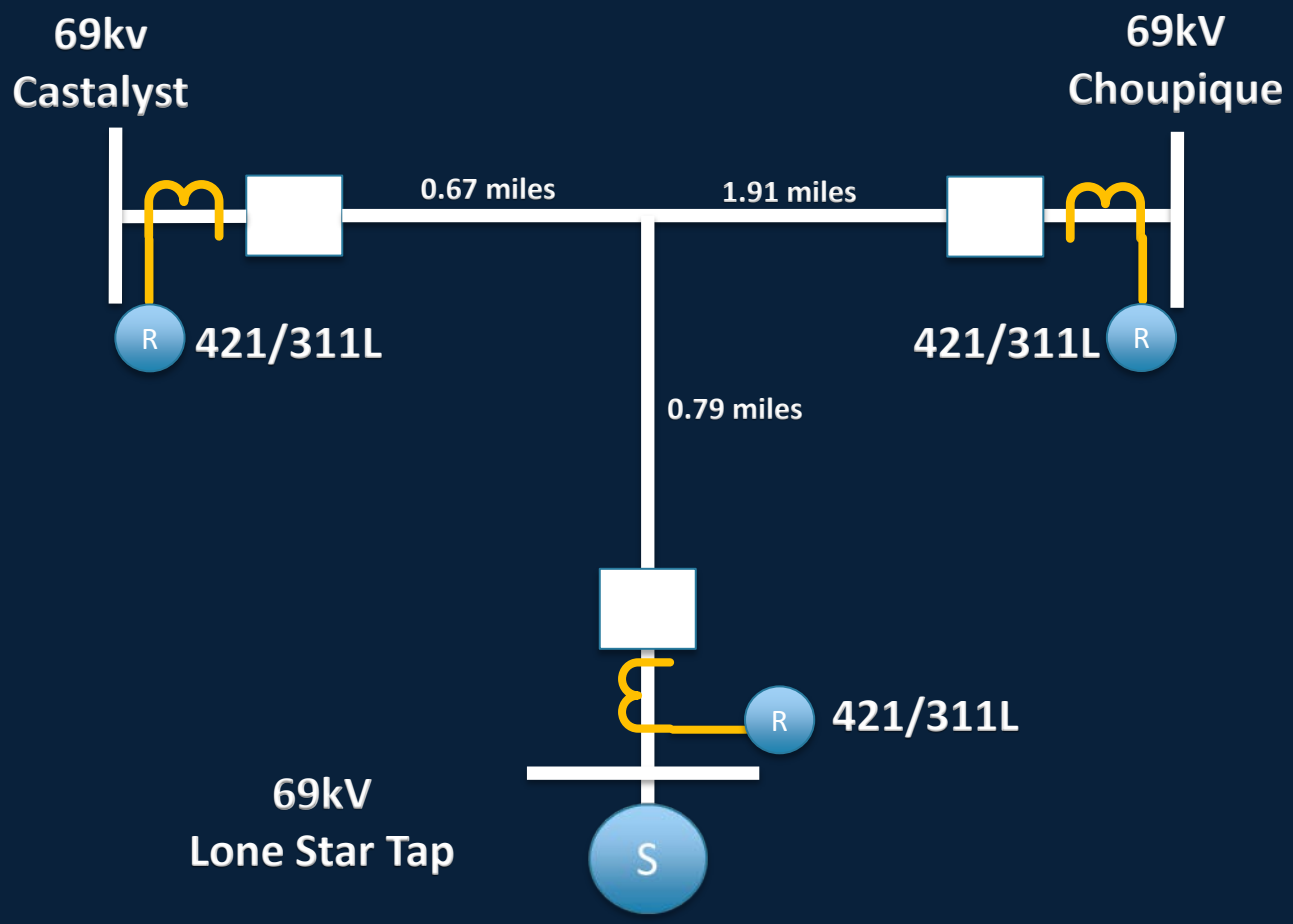
Chemical Process



Entergy Application



Entergy Application



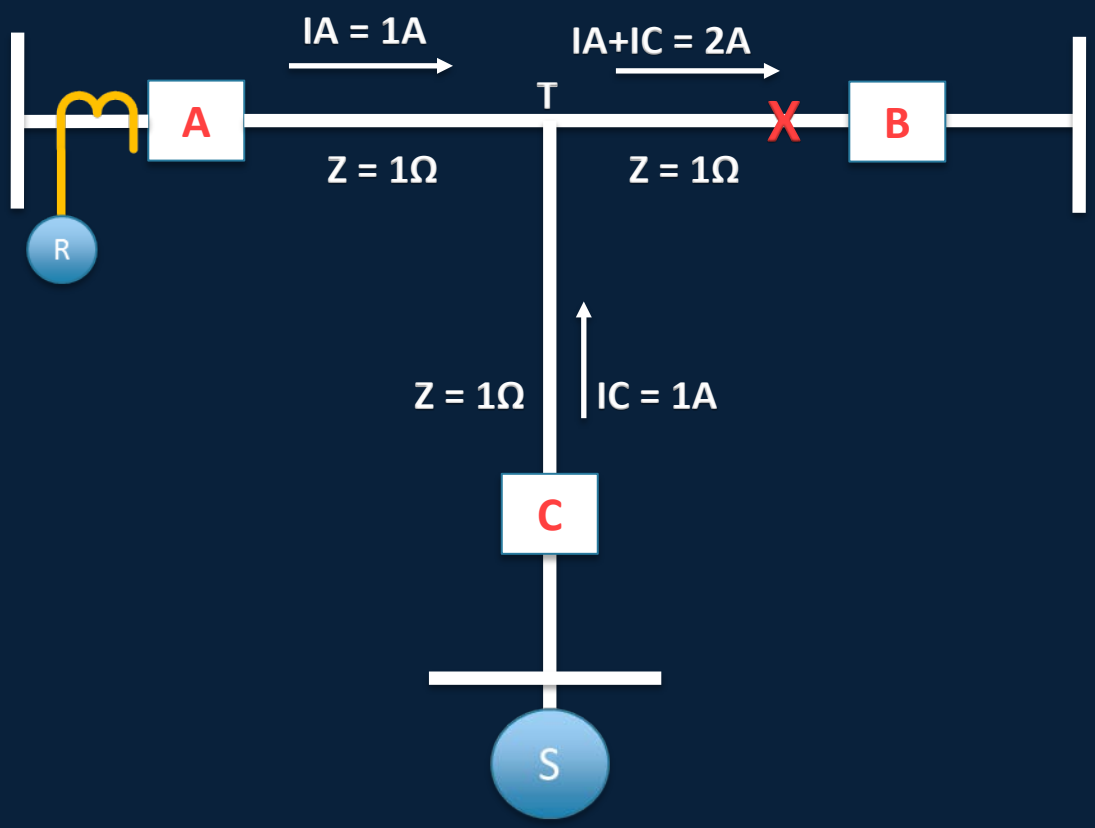
Protection of Three Terminal Lines

- Not as simple as two terminal lines
- Infinite variety of
  - Tap locations
  - Line impedances
  - Source impedances
  - System loading
  - System operations
- Infeeds
- Outfeeds

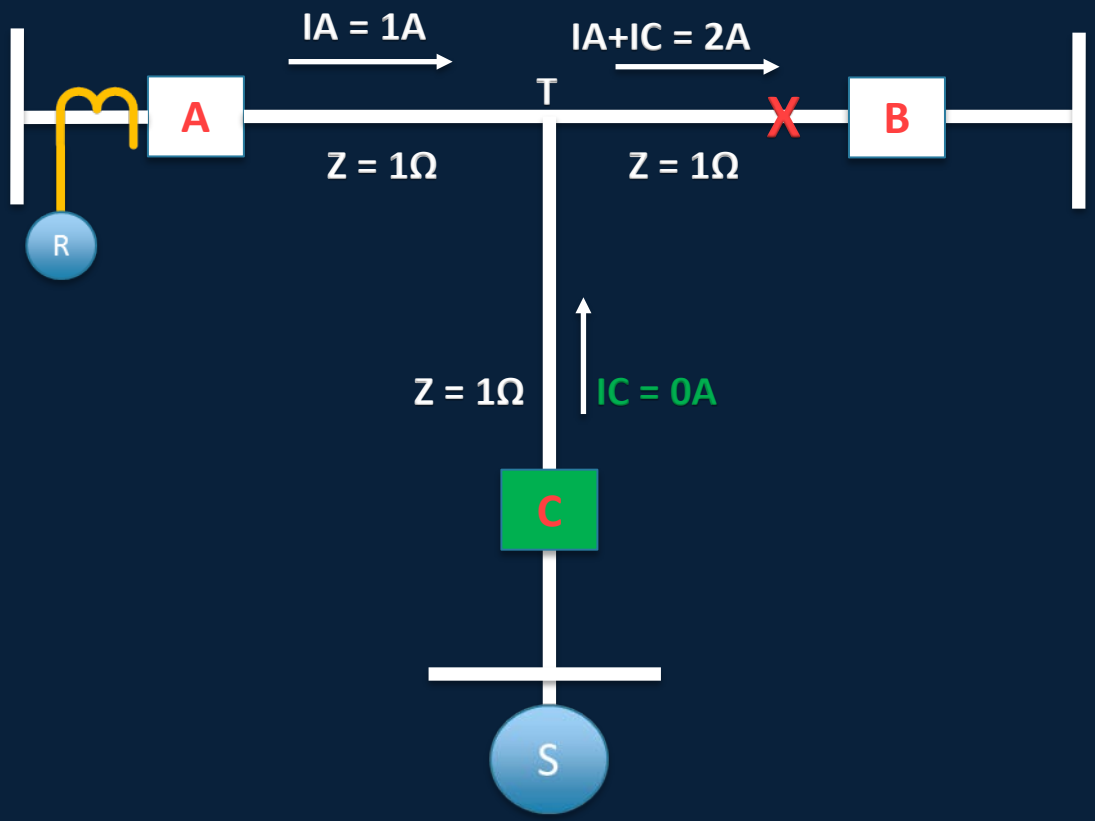
Apparent Impedance

- Impedance seen by relay does not equal line impedance from the relay terminal to fault.
- Relay measures voltage drop between relay location and fault.
- Impedance seen by relay depends on contributions or infeed from other terminals.
- Let’s review the infeed problem.

Apparent Impedance and Infeed



Apparent Impedance and Infeed



$$VA = VAT + VTF$$

$$= IA * ZAT + IA * ZTF$$

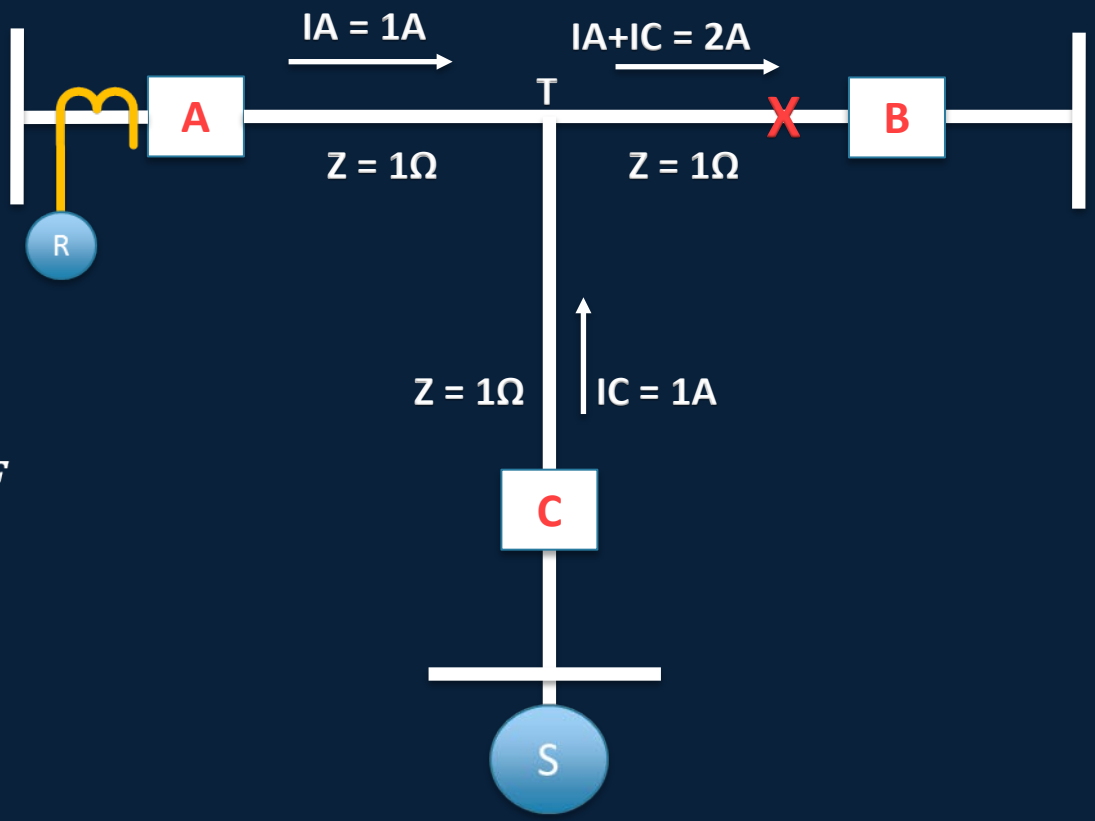
$$= IA(ZAT + ZTF)$$

$$= IA * ZAF$$

The true impedance is:

$$ZAF = \frac{VA}{IA} = 2\Omega$$

Apparent Impedance and Infeed



$$VA = VAT + VTF$$

$$= IA * ZAT + (IA + IC) * ZTF$$

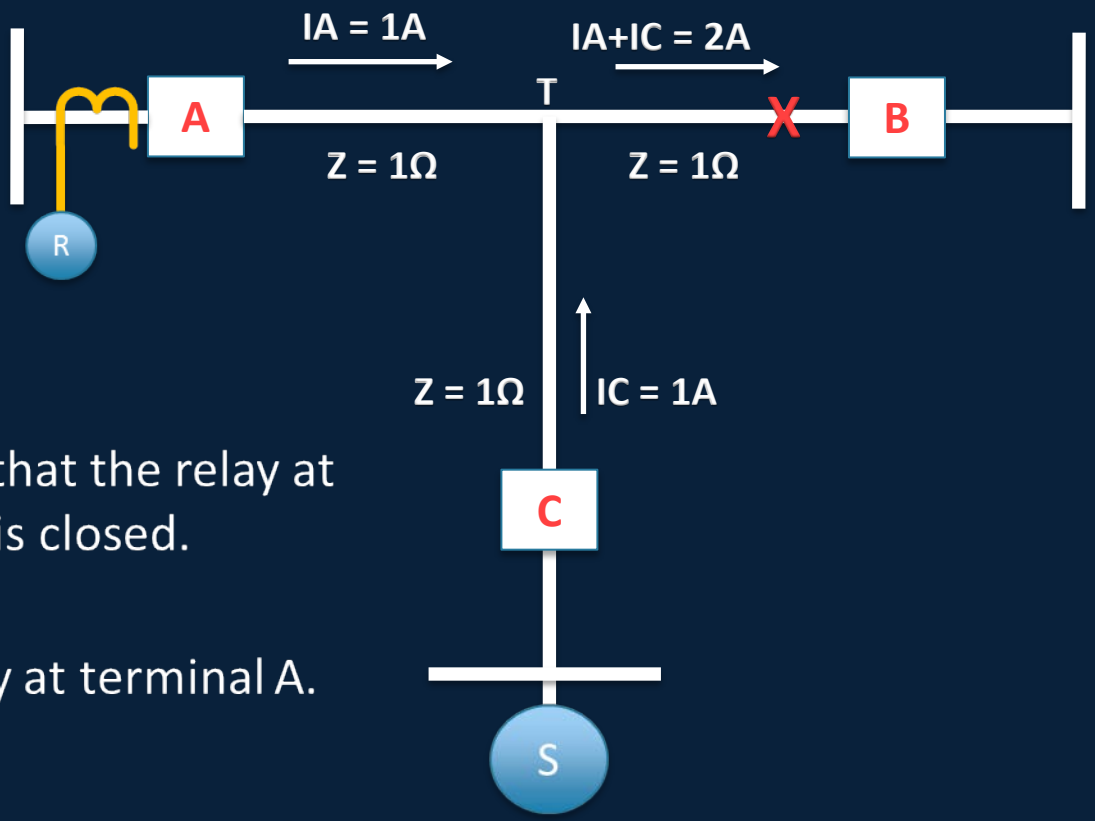
$$= IA * ZAT + IA * ZTF + IC * ZTF$$

$$= IA * (ZAT + ZTF) + IC * ZTF$$

$$Zapp = \frac{VA}{IA} = ZAF + \frac{IC}{IA} * ZTF$$

$$Zapp = 2\Omega + \frac{1A}{1A} * 1\Omega = 3\Omega$$

Apparent Impedance and Infeed



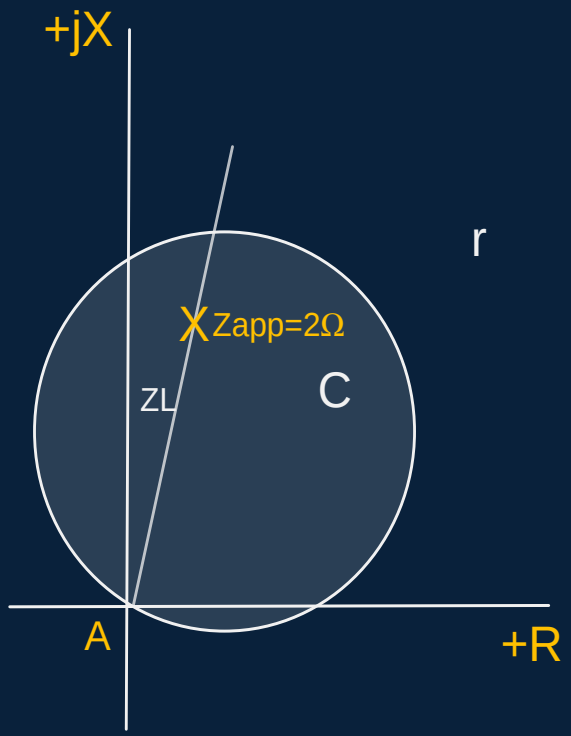
$$Zapp = \frac{VA}{IA} = ZAF + \frac{IC}{IA} * ZTF$$

Zapp is the apparent impedance that the relay at terminal A sees when terminal C is closed.

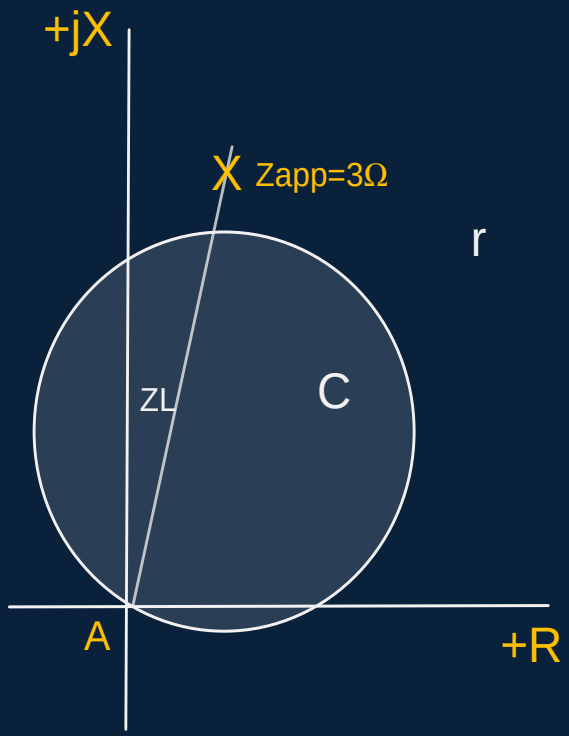
$\frac{IC}{IA}$ is the infeed factor for the relay at terminal A.

$\frac{IC}{IA}$ *ZTF is the error factor as a result of the infeed.

Apparent Impedance and Infeed

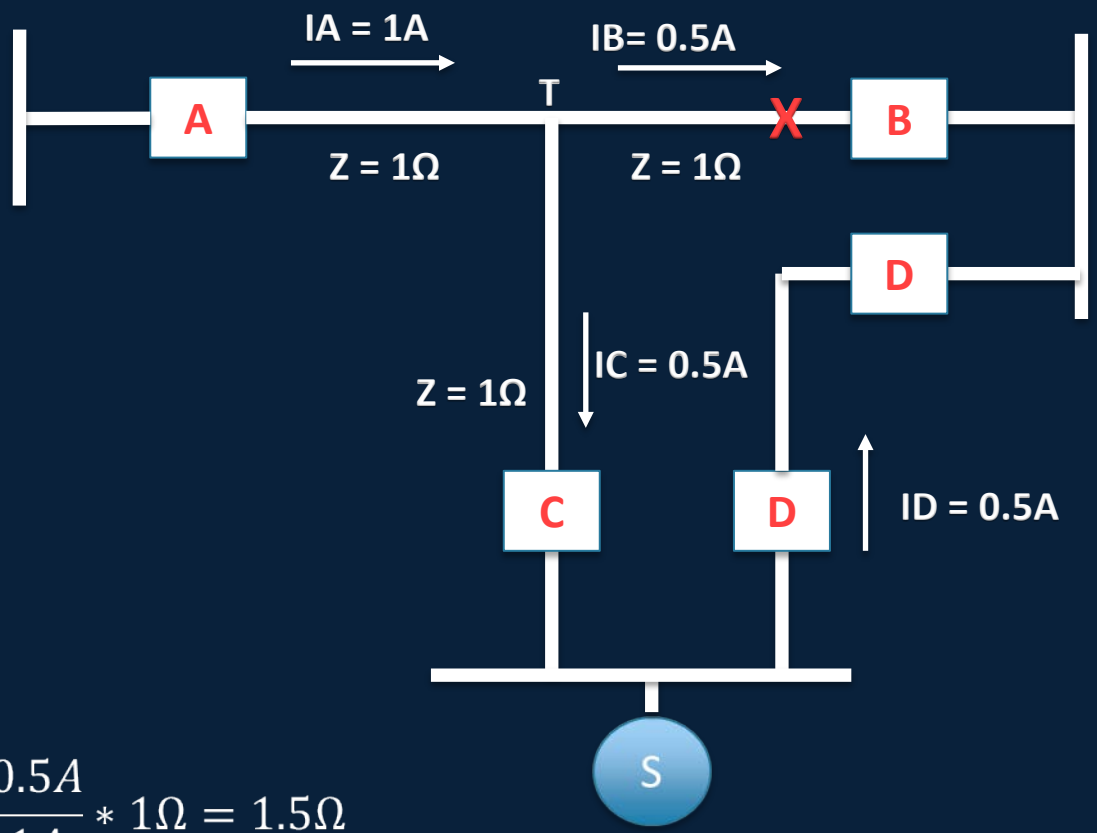


Zapp without Infeed



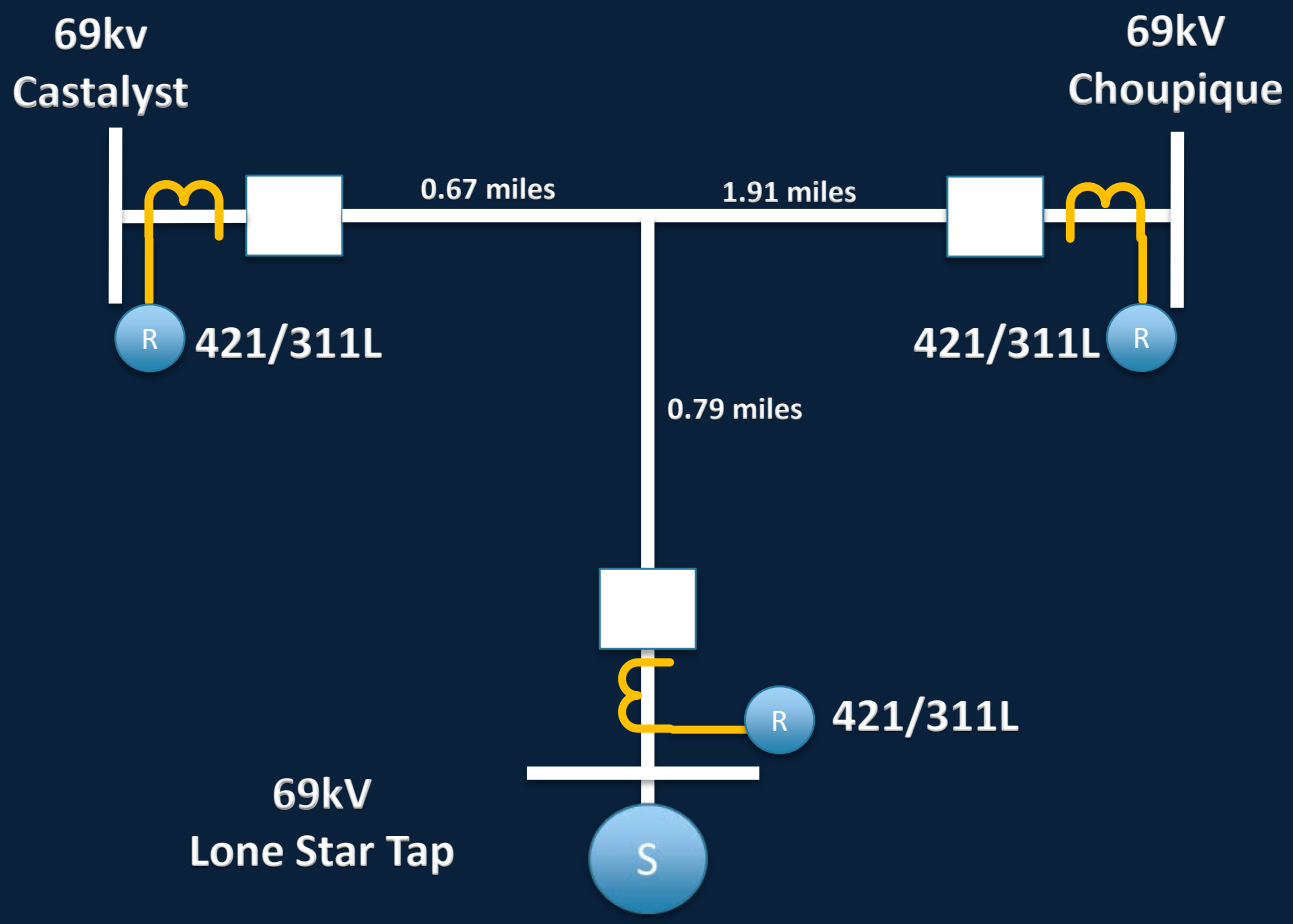
Zapp with Infeed

Apparent Impedance and Outfeed



$$Zapp = \ 2\Omega - \frac{0.5A}{1A} * 1\Omega = 1.5\Omega$$

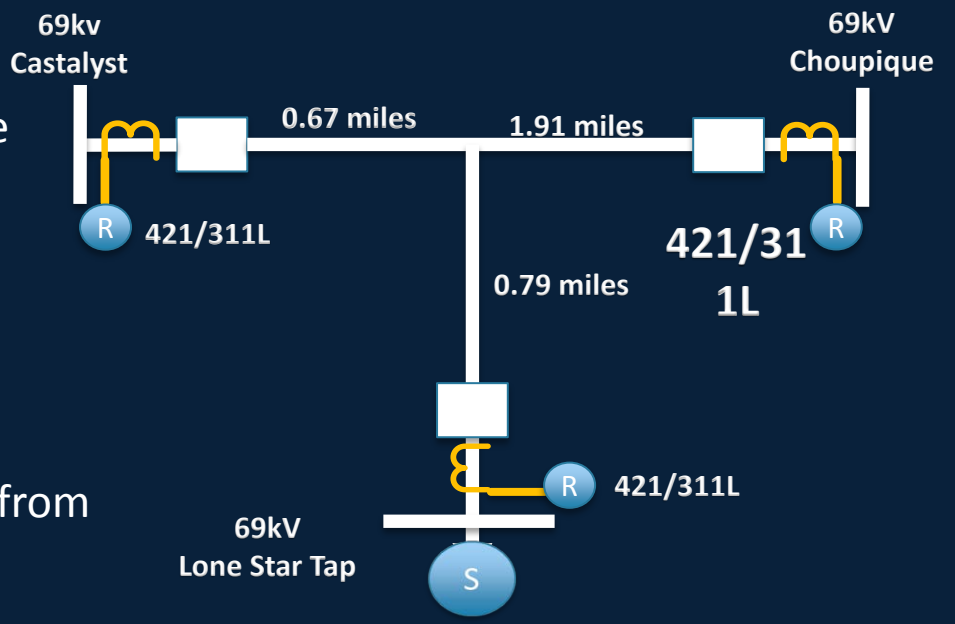
421-Relay Settings



421-Directional Settings

Station R = Catalyst Station S = Choupique
Station T = Lone Star

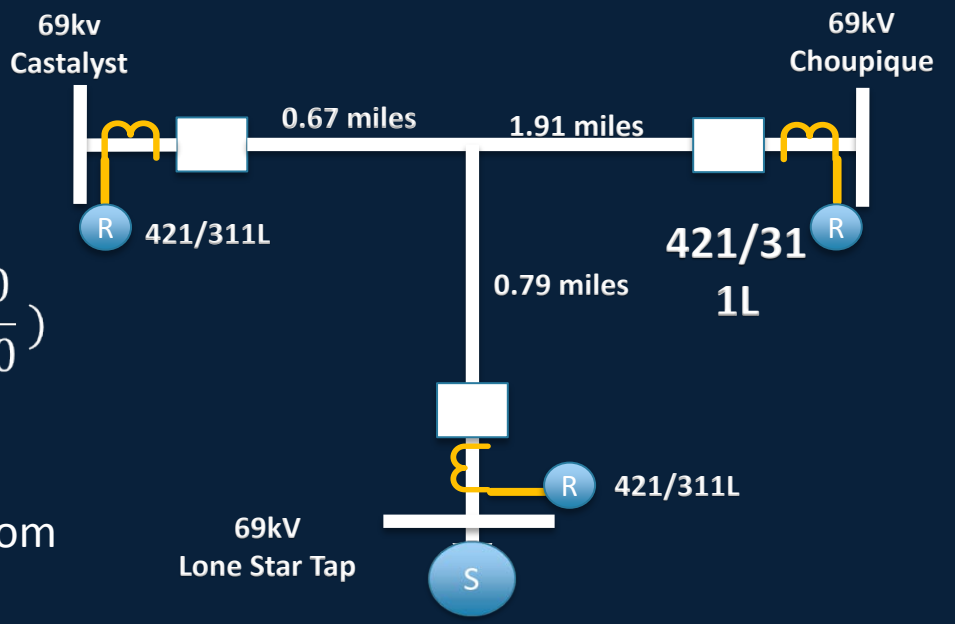
$$Z2F = 0.5 * (ZRTap + \frac{ZSTap * ZTTap}{ZSTap + ZTTap})$$



- ZRTap is the positive sequence impedance from station R to the Tap point.
- ZSTap is the positive sequence impedance from station S to the Tap point.
- ZTTap is the positive sequence impedance from station T to the Tap point.

421- Directional Settings

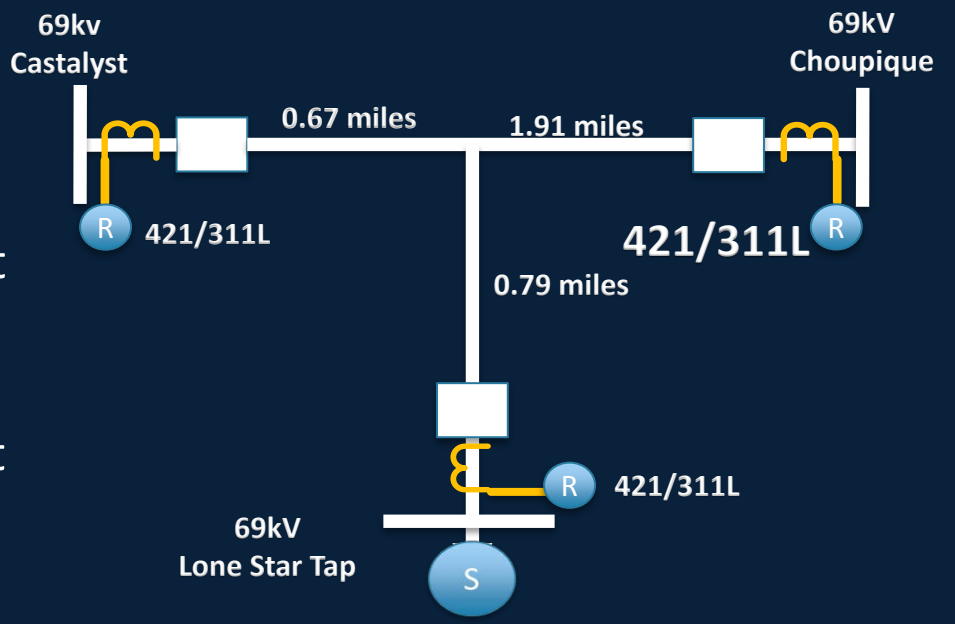
$$Z0F = 0.5 * (ZRTap0 + \frac{ZSTap0 * ZTTap0}{ZSTap0 + ZTTap0})$$



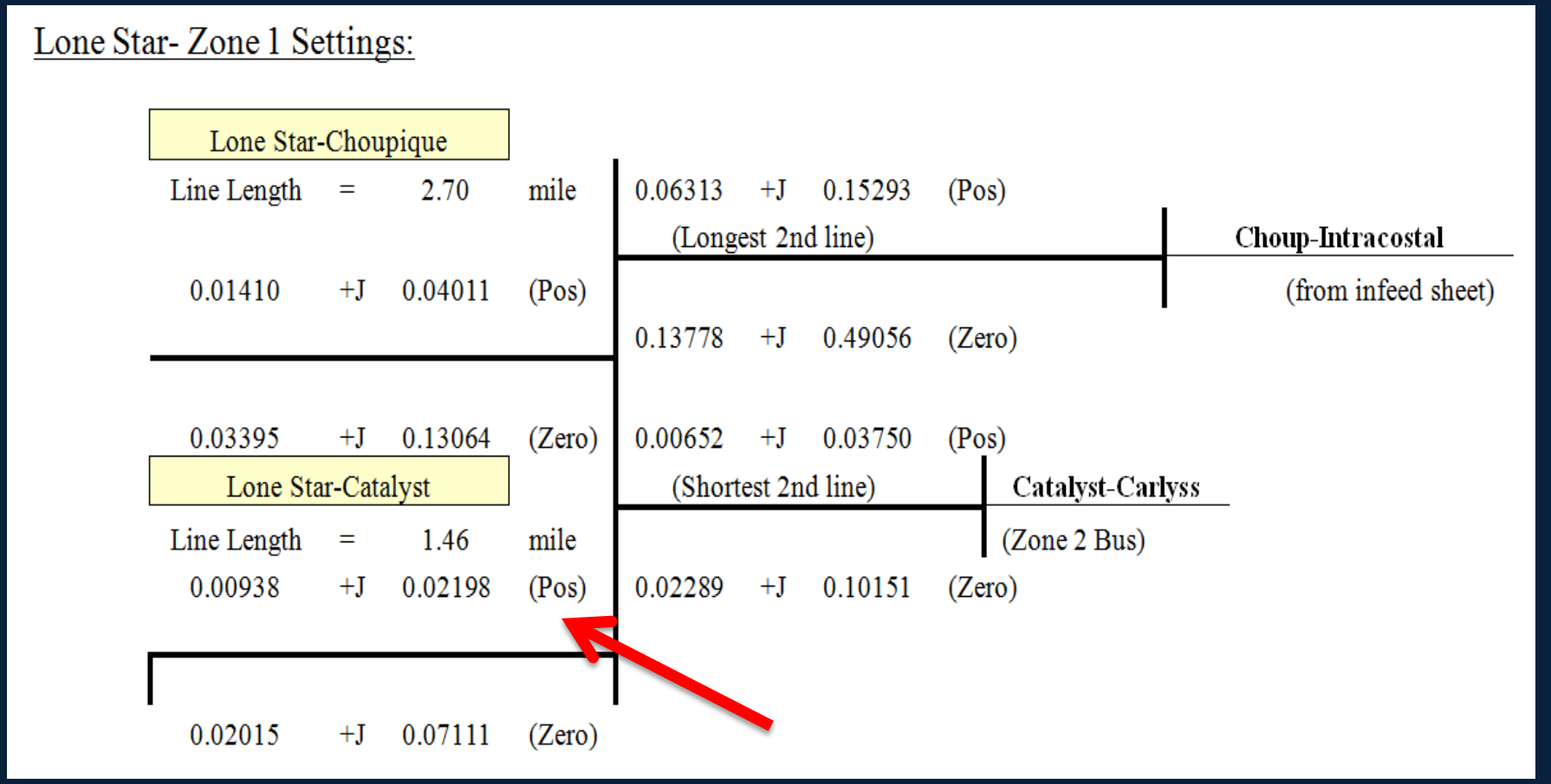
- ZRTap0 is the zero sequence impedance from station R to the Tap point.
- ZSTap0 is the zero sequence impedance from station S to the Tap point.
- ZTTap0 is the zero sequence impedance from station T to the Tap point.

421-Zone 1 Settings

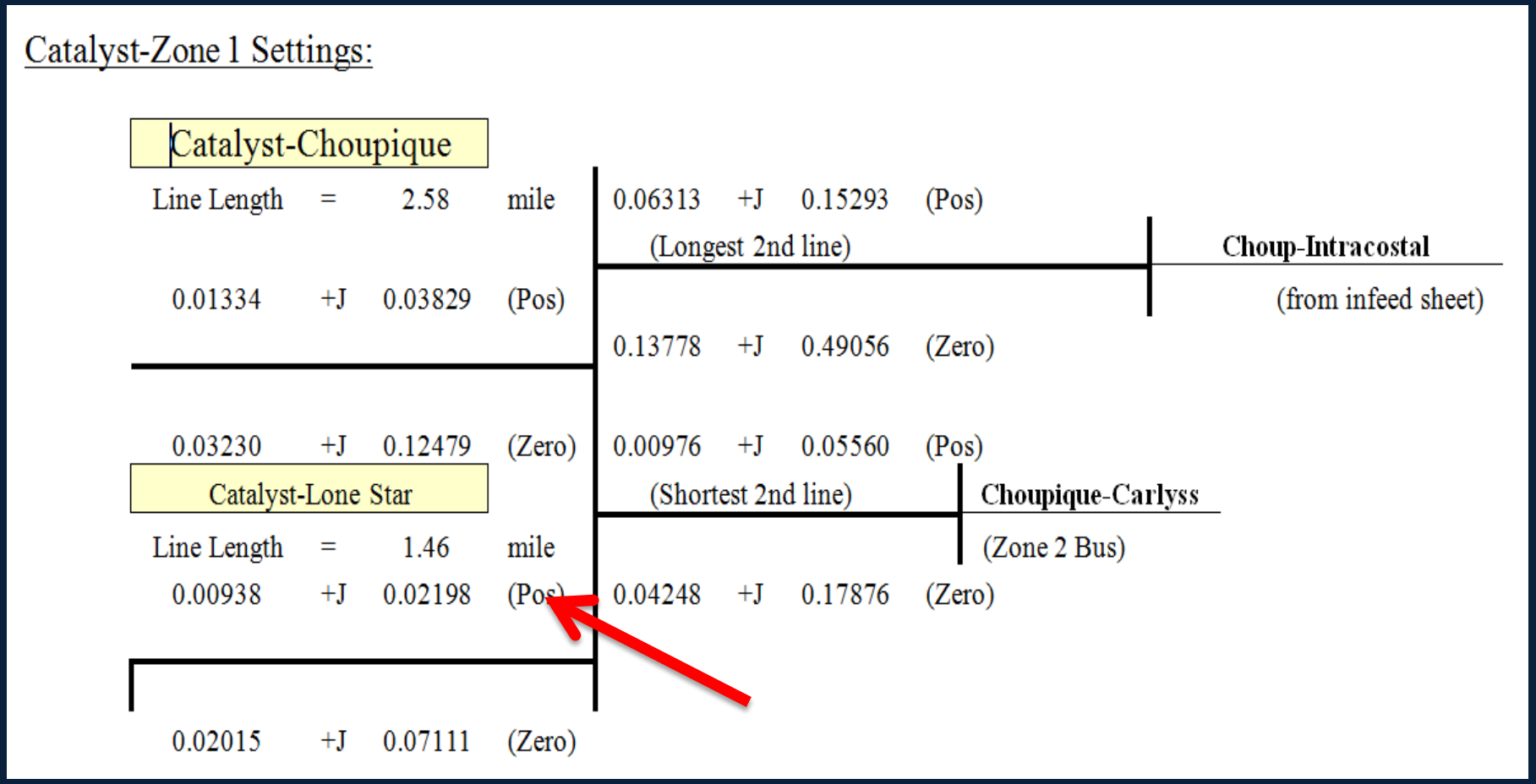
- Zone 1 settings should be selected based on the shortest line to the next terminal.
- Zone 1 settings need to be set so that they do not overreach any of the remote terminals.
- Zone 1 settings should be 80% of the line.
- All Zone 1 elements work under a DUTT.



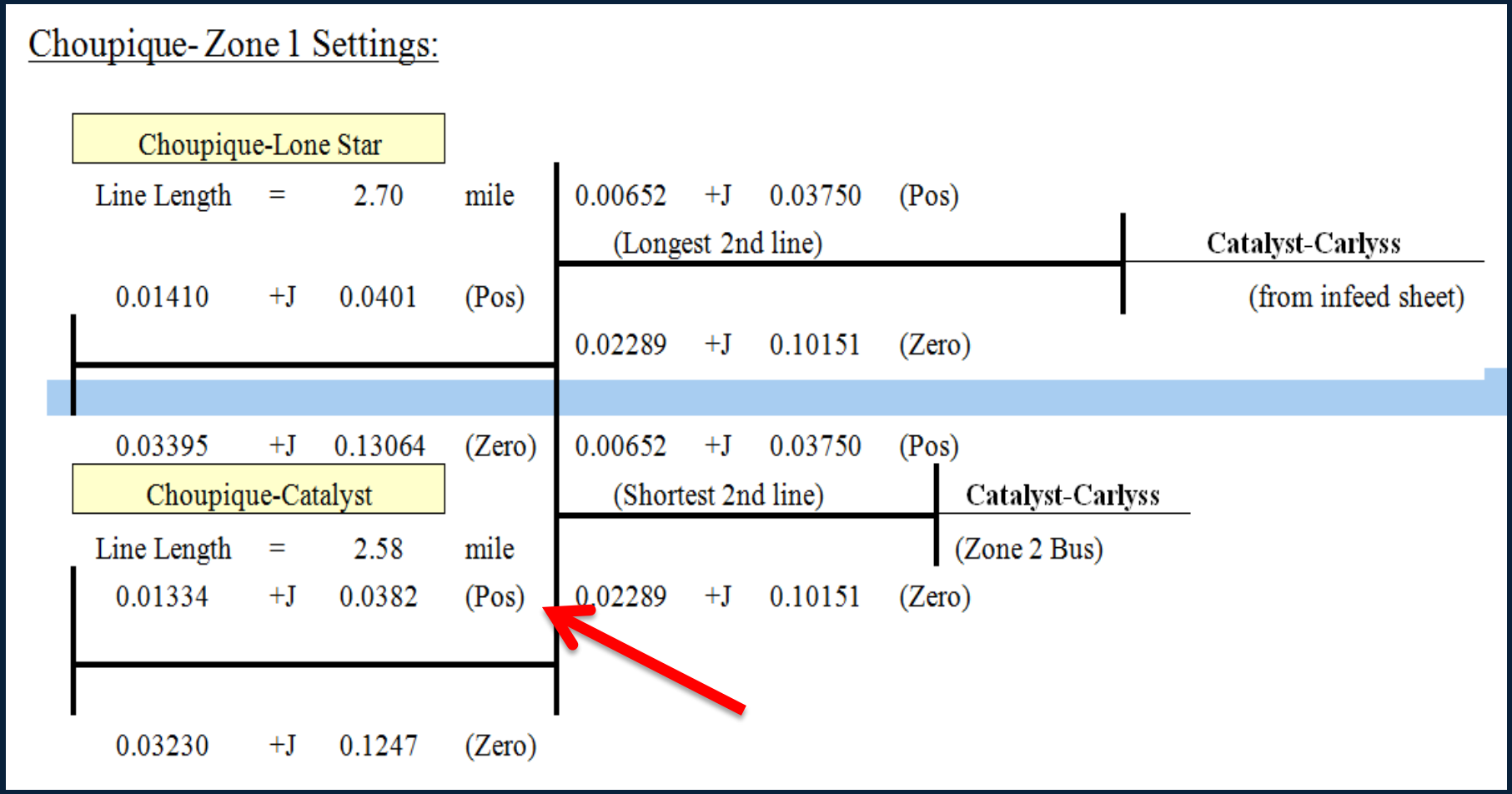
421-Zone 1 Settings



421-Zone 1 Settings



421-Zone 1 Settings



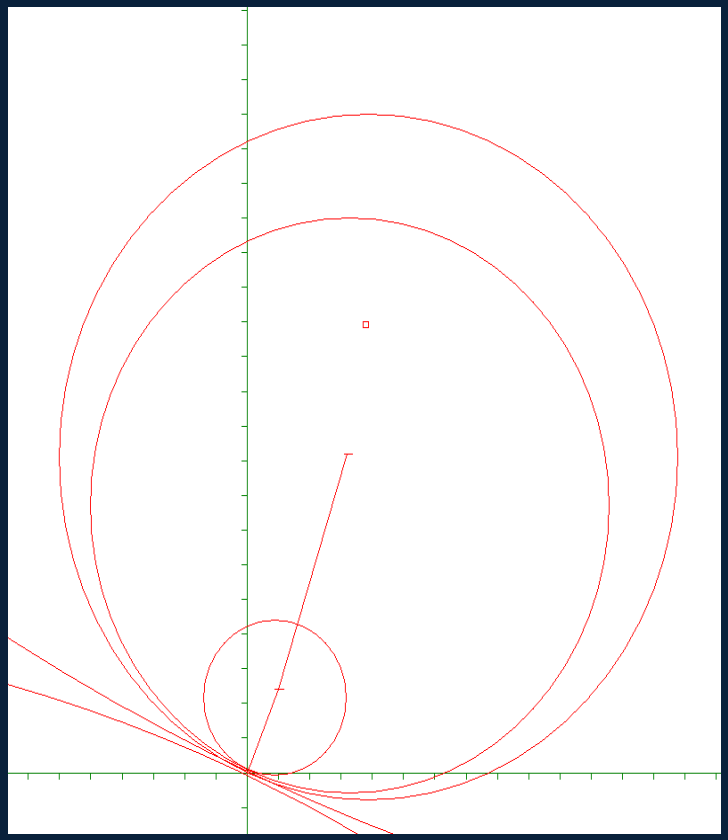
421-Zone 2 Settings

- Zone 2 is set between
  - 120% of the line impedance and
  - 100% of the secondary line impedance plus 50% of the secondary line impedance of the remote shortest line.
- Zone 2 elements must detect all internal faults.
- Zone 2 elements are used for the permissive trip elements with a POTT scheme.
- Zone 2 elements are affected by the infeed currents.
- Zone 2 elements must be verified using the Apparent Impedance through Aspen.

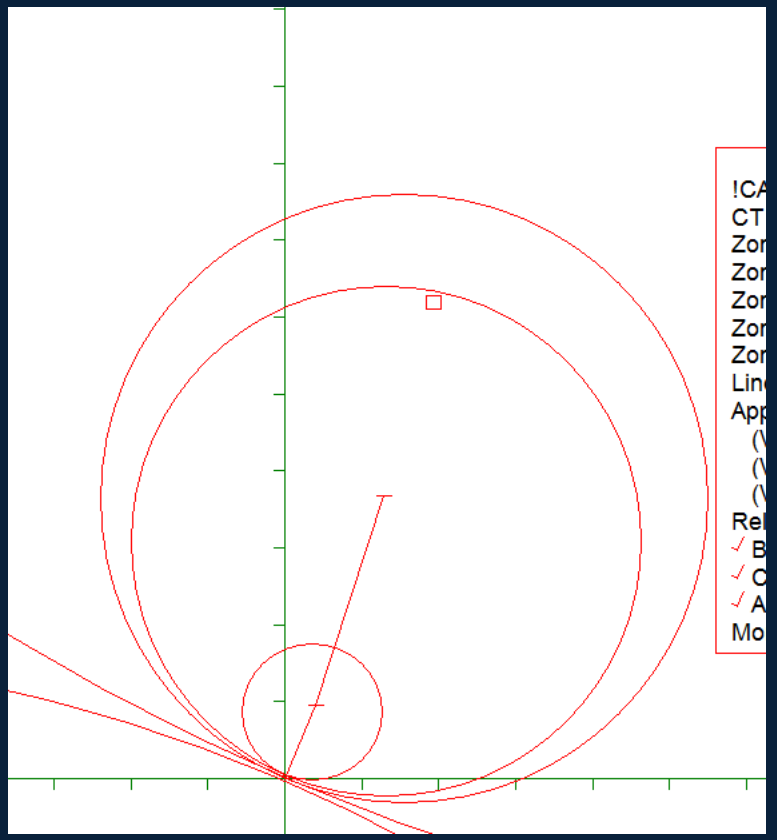
421-Zone 2 Settings

Zone 2 Settings Carlyss set at 2.19 ohms from calculation sheet

Apparent Impedance Lone Star
Open, fault at 124% of the line: 1.77 ohms



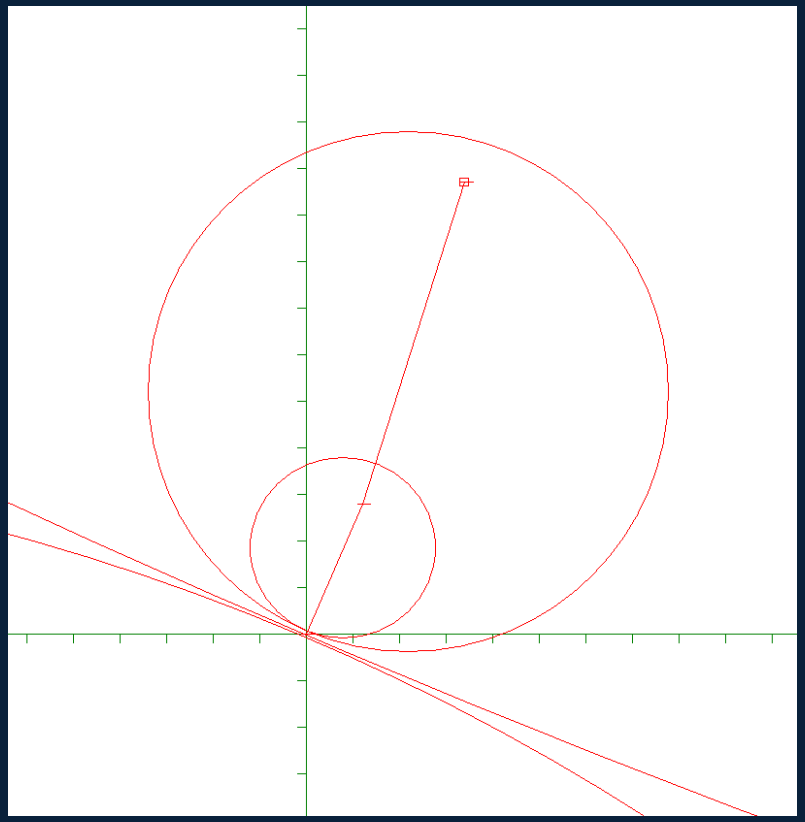
Apparent Impedance Lone Star
Closed, fault at 124% of the line: 2.14 ohms



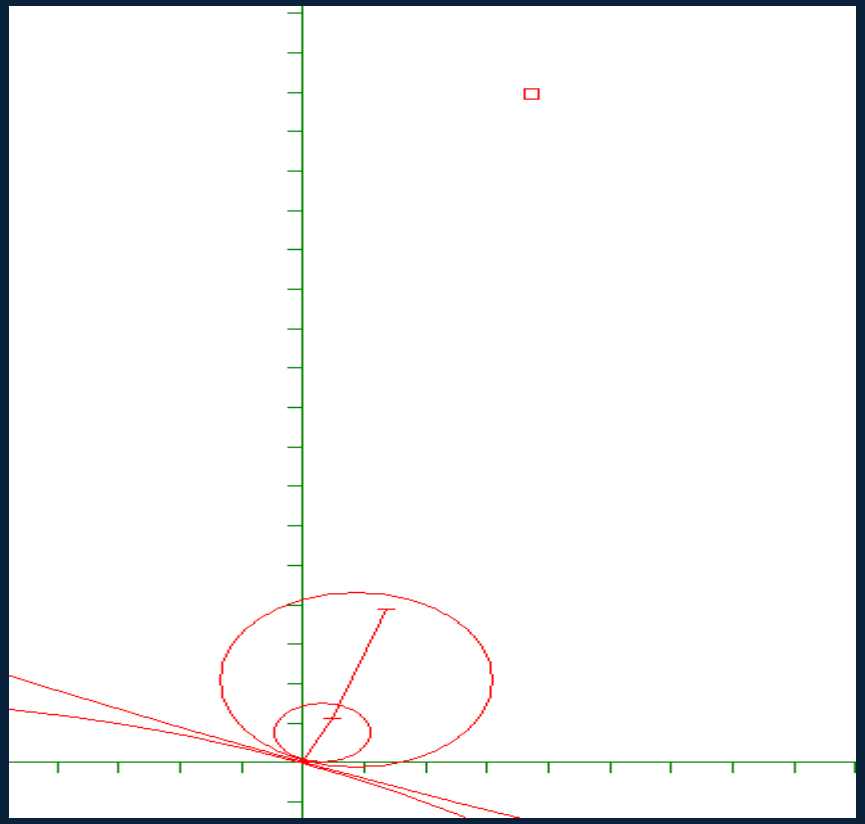
421-Zone 2 Settings

Zone 2 Settings Lone Star set at 1.48 ohms from calculation sheet

Apparent Impedance Carlyss Open, fault at 100 % of the line: 1.48 ohms

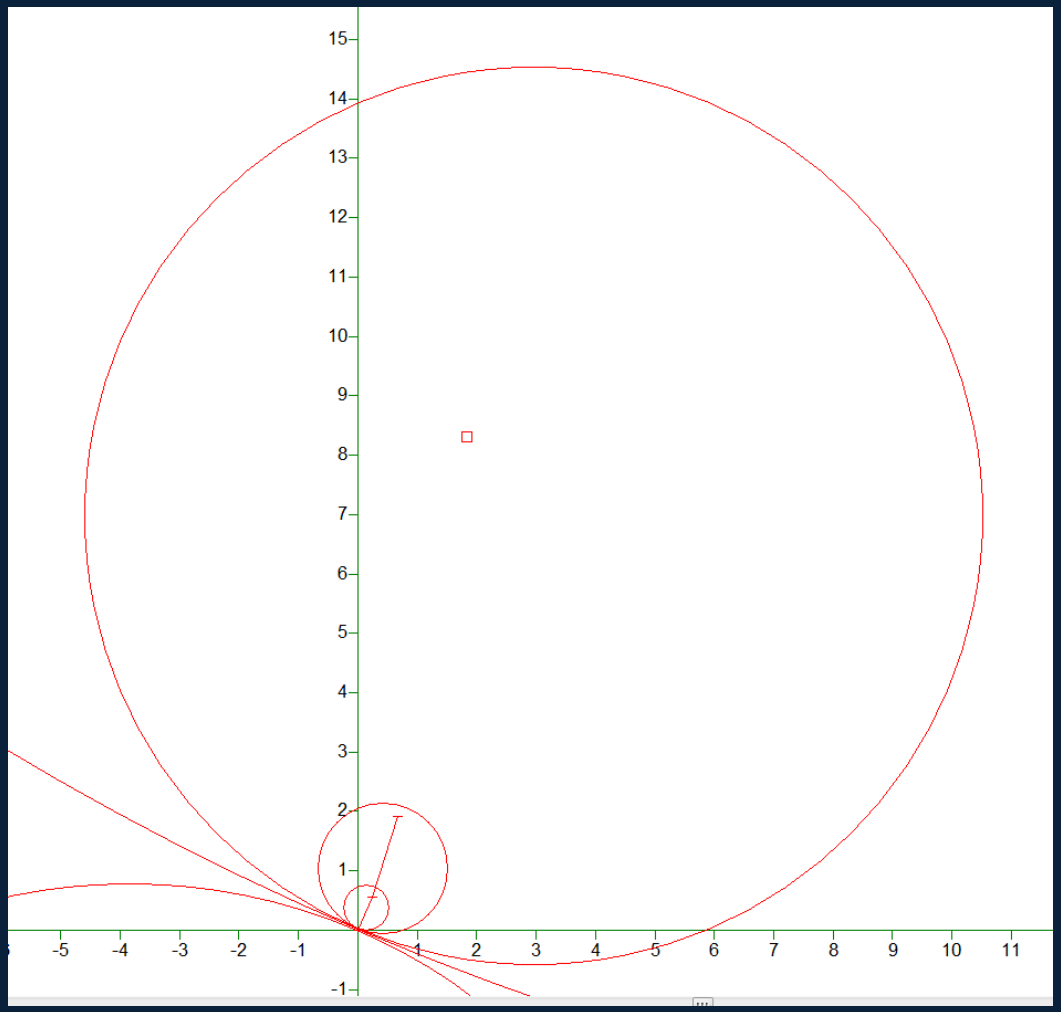


Apparent Impedance Carlyss Closed, fault at 100 % of the line: 5.68 ohms



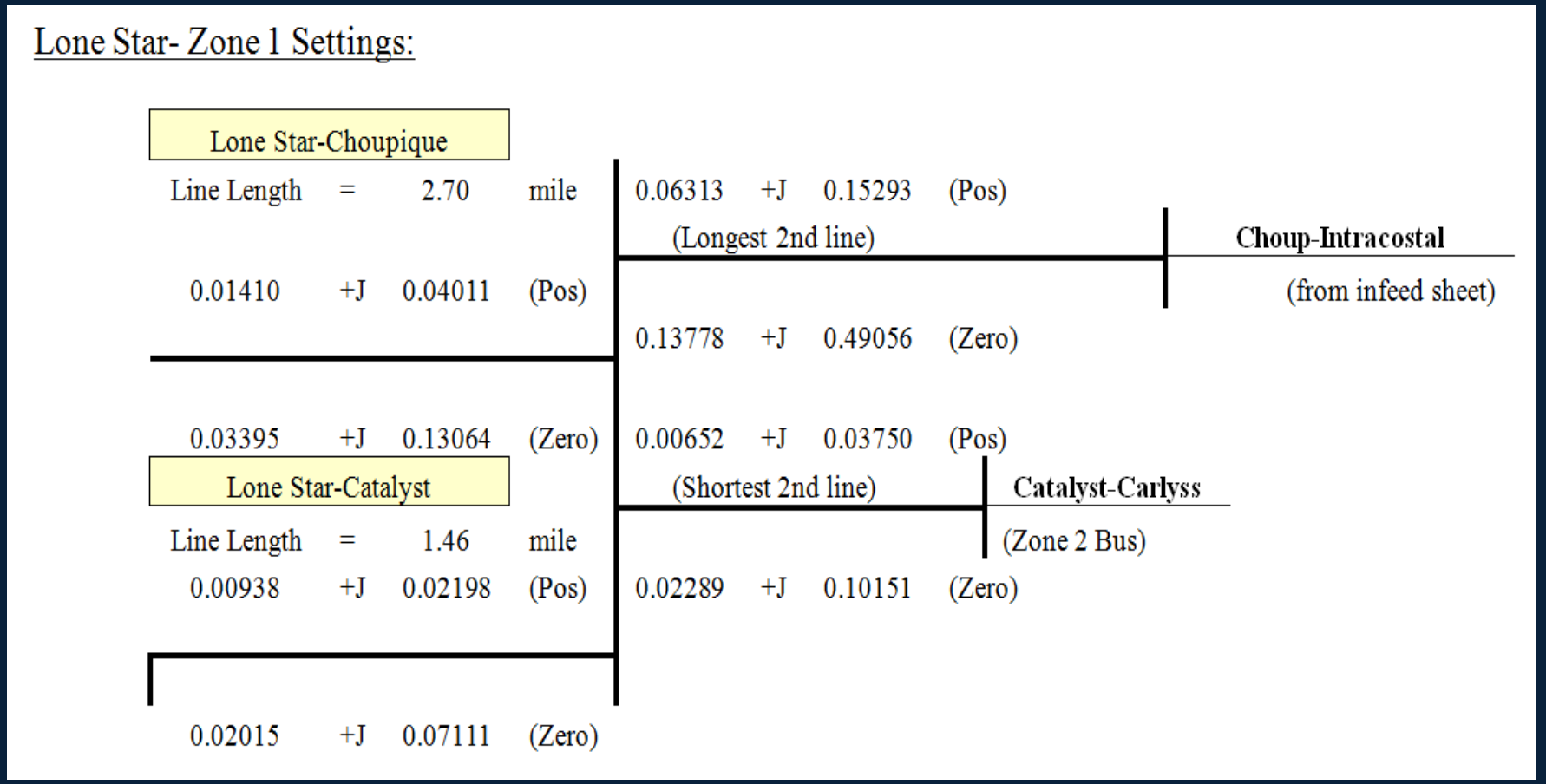
421-Zone 2 Settings

Zone 2 Settings Lone Star set at 10.1 ohms from Zapp



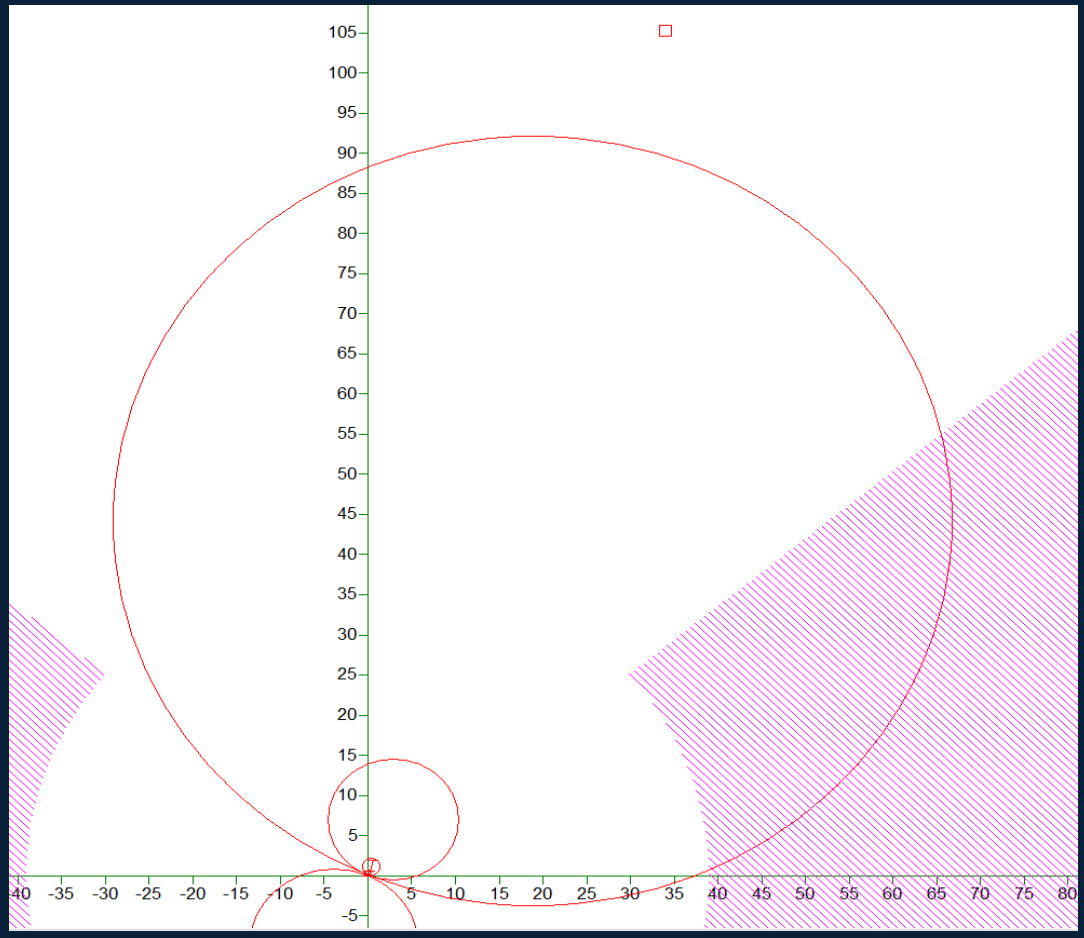
421-Zone 3 FWD Settings

Set Zone 3 Forward to see a fault to the end of the second longest line with line end open

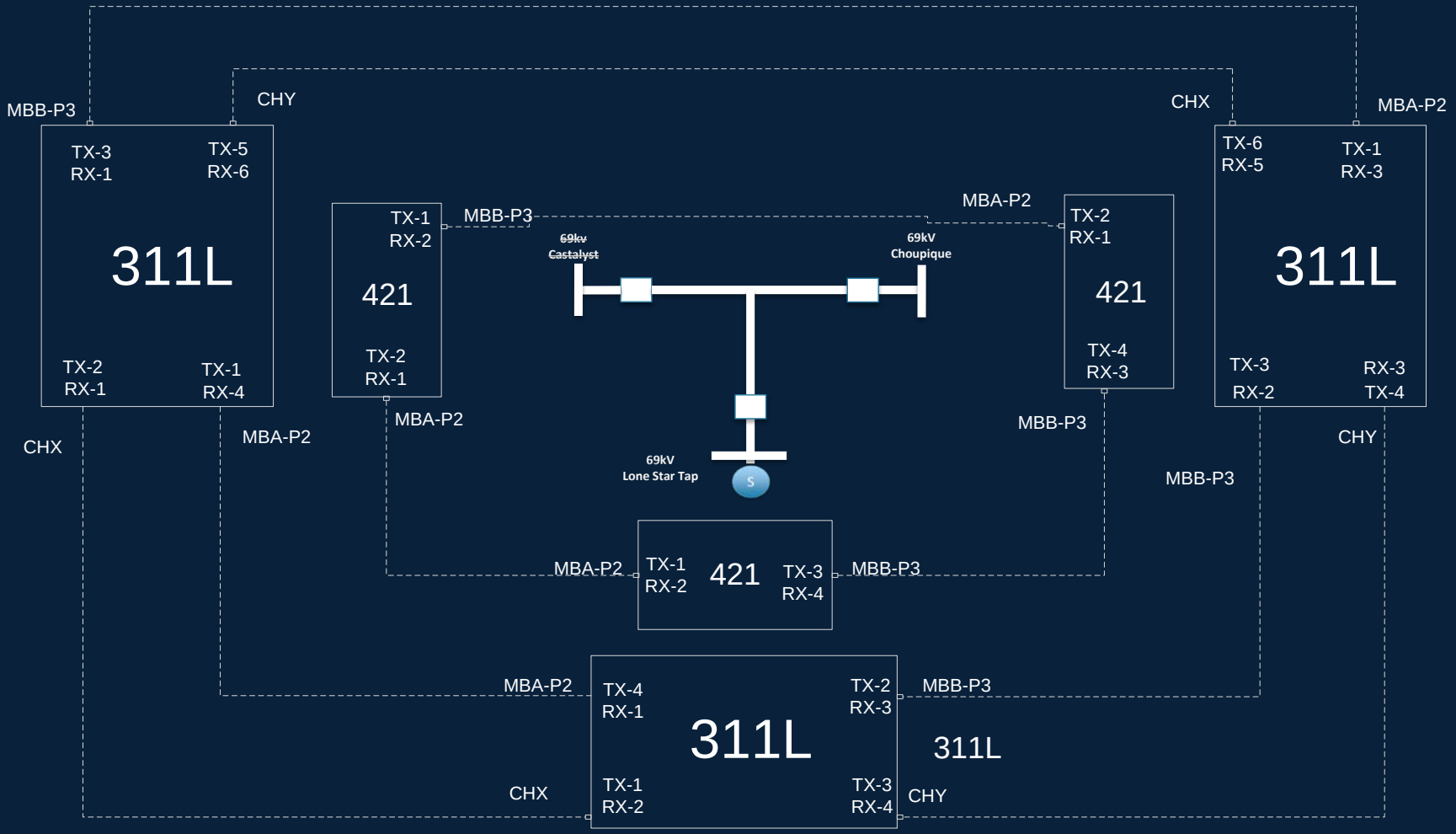


421-Zone 3 FWD Settings

- Zone 3 Settings Lone Star set at max 64 ohms
- Sequential tripping

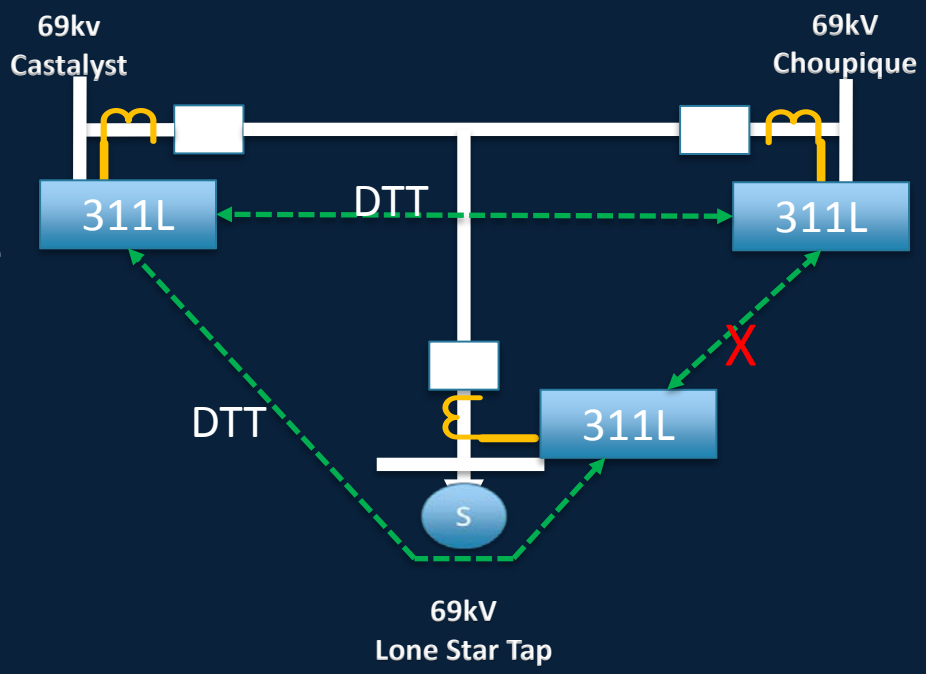


Communications

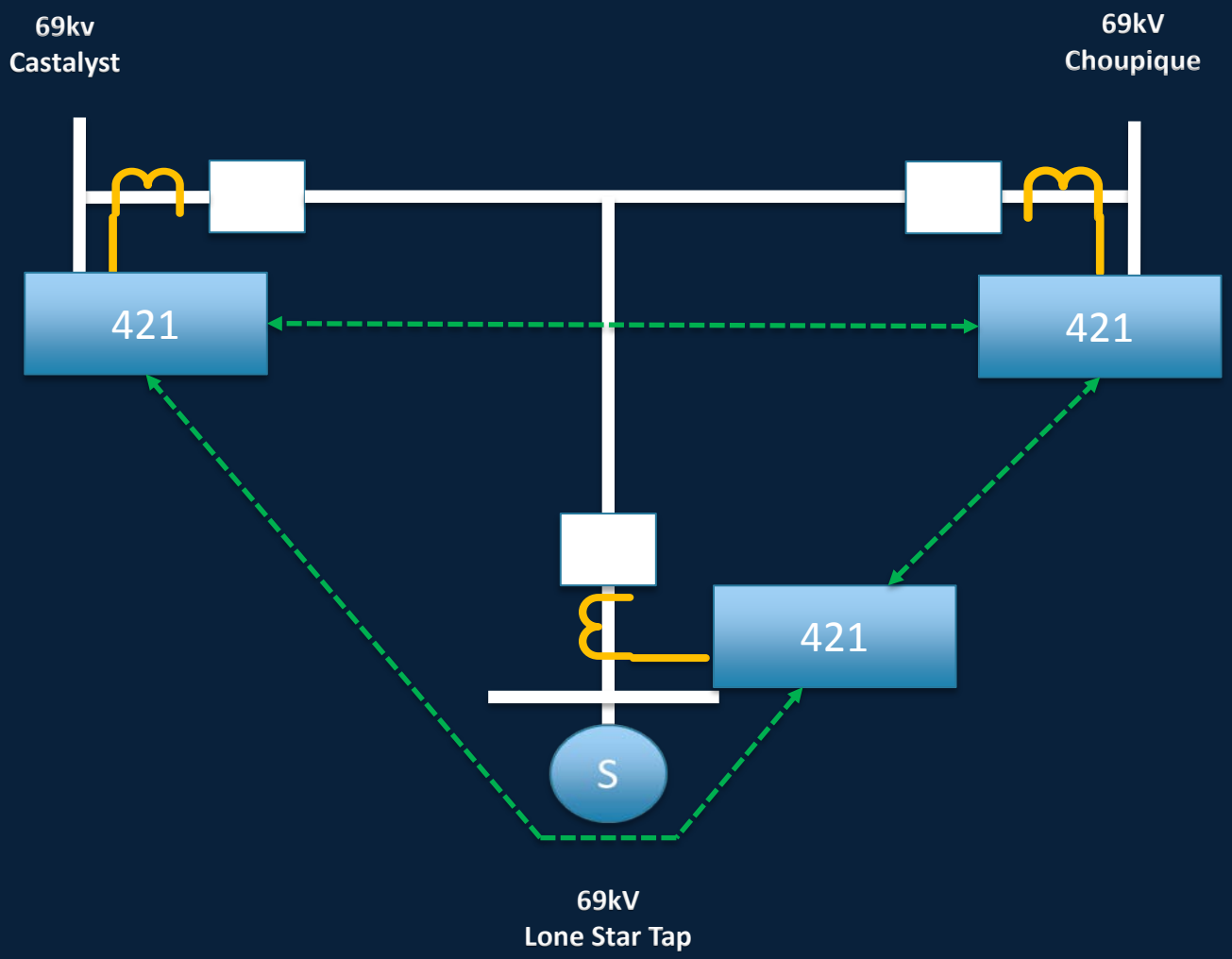


Communications

- 311L combines two terminal line currents into single current.
- SEL 311L applies two terminal line algorithms to three terminal line applications.
- Loss of communication channel relay with two healthy channels protection still maintained.
- In addition, scheme changed into a DTT.

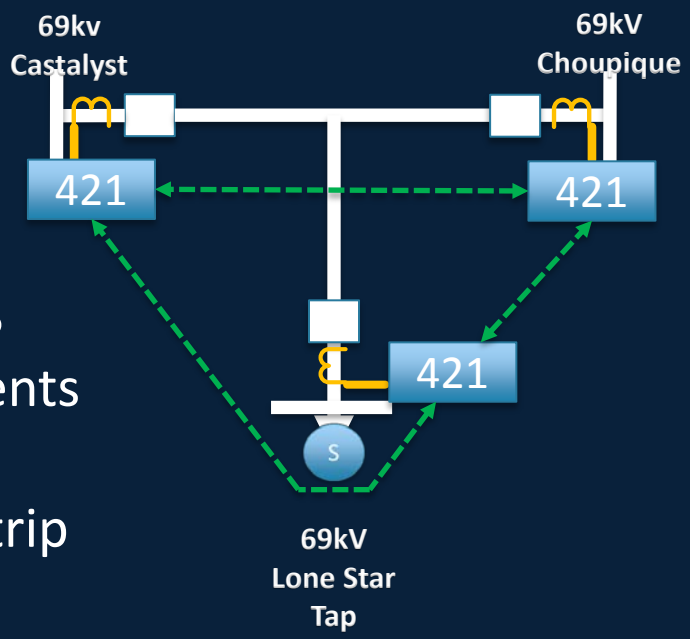


Communications

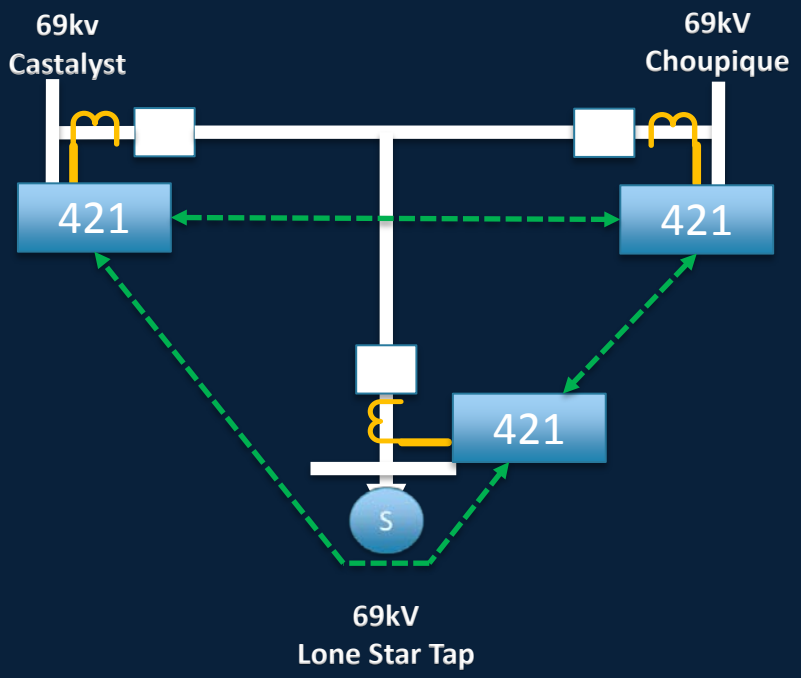


Communications

- DUTT scheme for Zone 1 elements
  - Trips all terminals via MBA and MBB
- POTT scheme for all overreaching elements
  - PT sent via MBA and MBB
- Terminal must receive a PT to initiate a trip
- In case of communication loss, MBs are passed through each communication channel to reach second remote bus.
- Echo logic enabled



Questions



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