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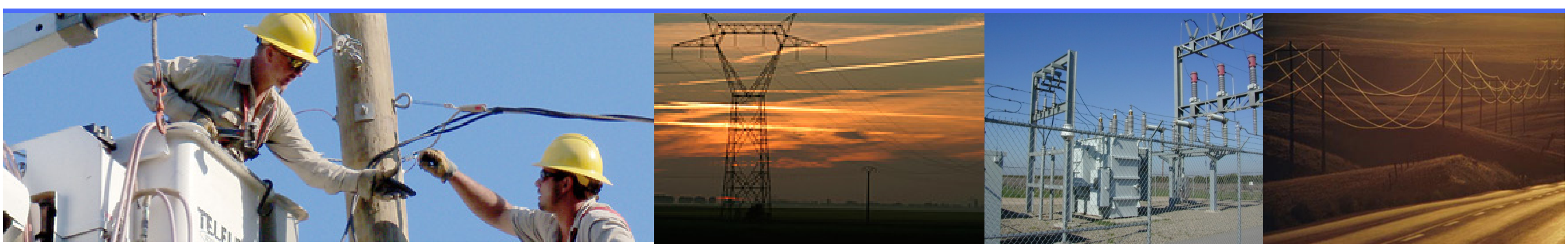
Engineering Reliability…
Empowering Utilities

Lessons Learned in Protective Relaying

Presented By:
Edd H. Lovette III, PE
PowerServices, Inc.

February 10, 2015

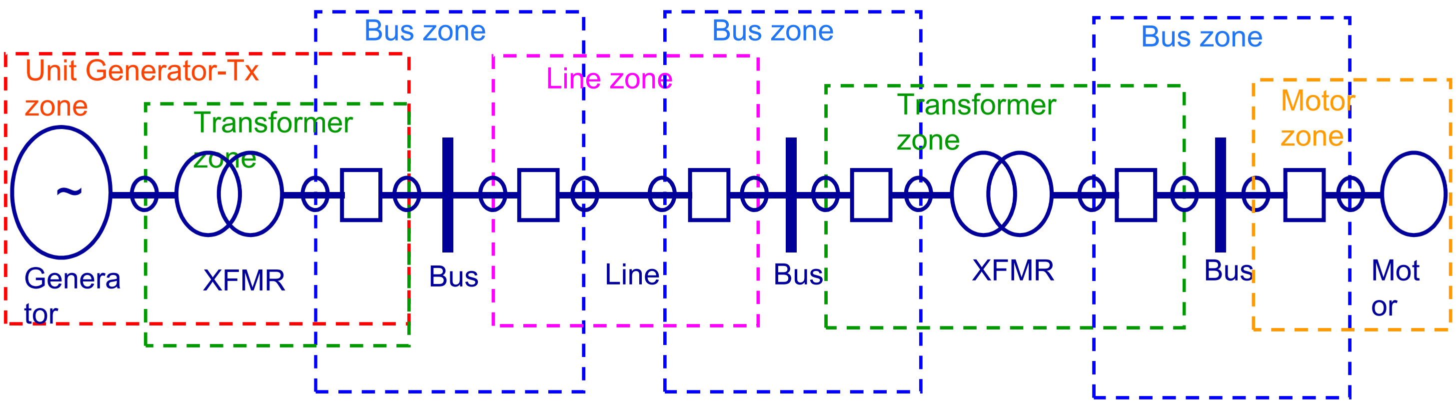


Overview

- Protective Relaying Overview
- Three “Lessons Learned” Case Studies

Protective Relaying Overview

- Protects Electrical Grid
- Monitors Current and Voltage
- Looks for Disturbances
- Opens Protective Devices

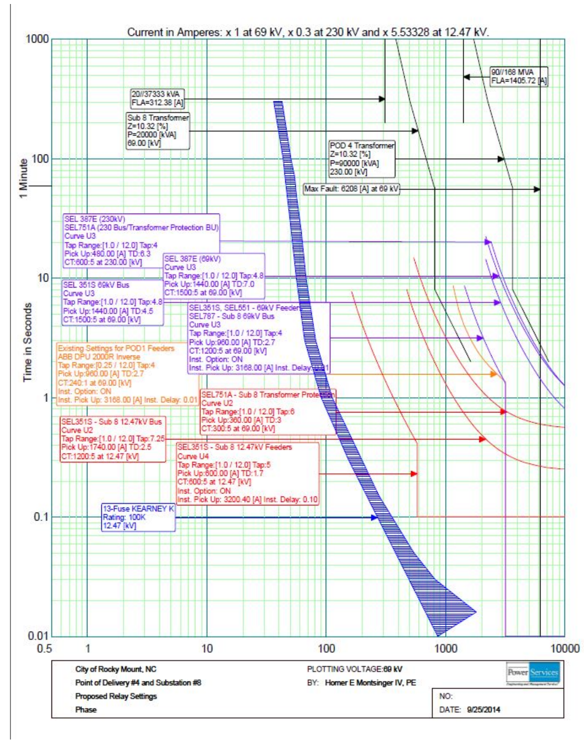


Protective Relaying Overview

Protective Relaying Overview

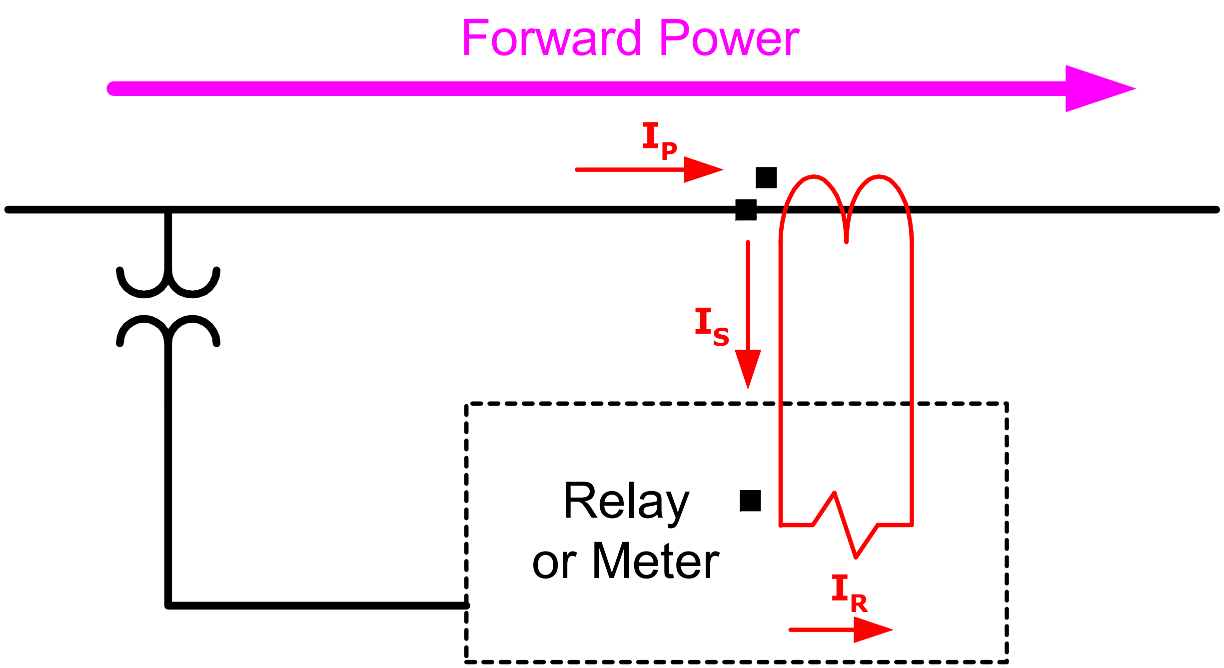
Objectives of System Protection

- Reliability / Resiliency
- Selectivity / Coordination
- Simplicity



Protective Relaying Overview

How Does a Protective Relay Work?



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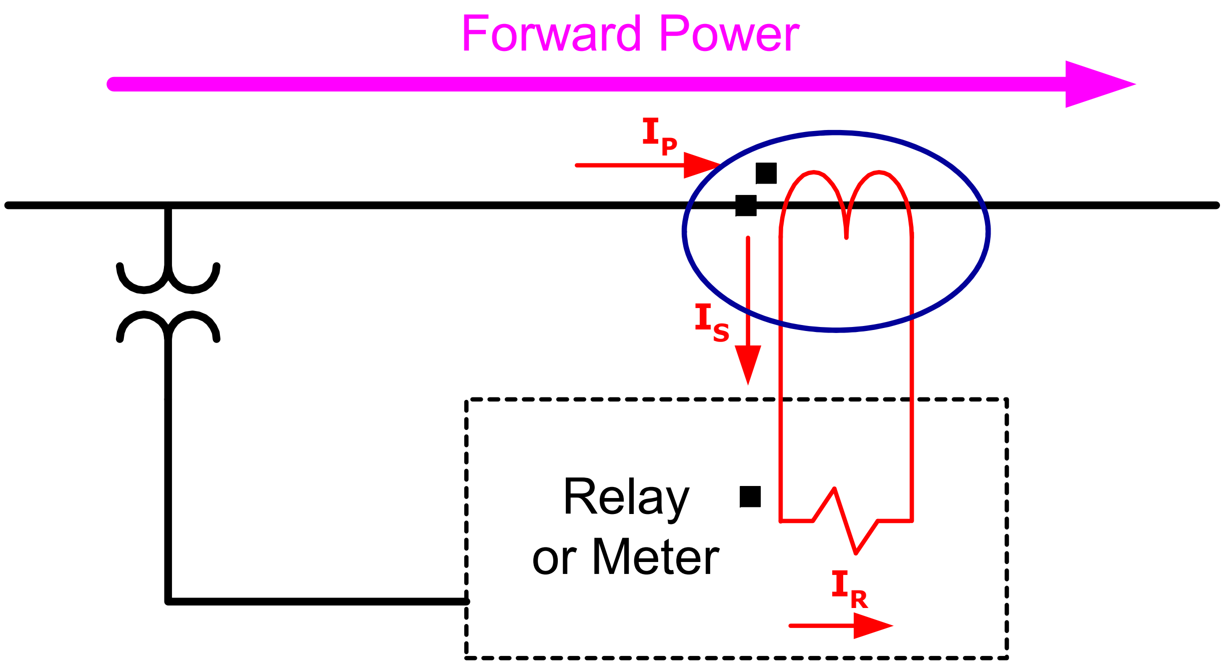

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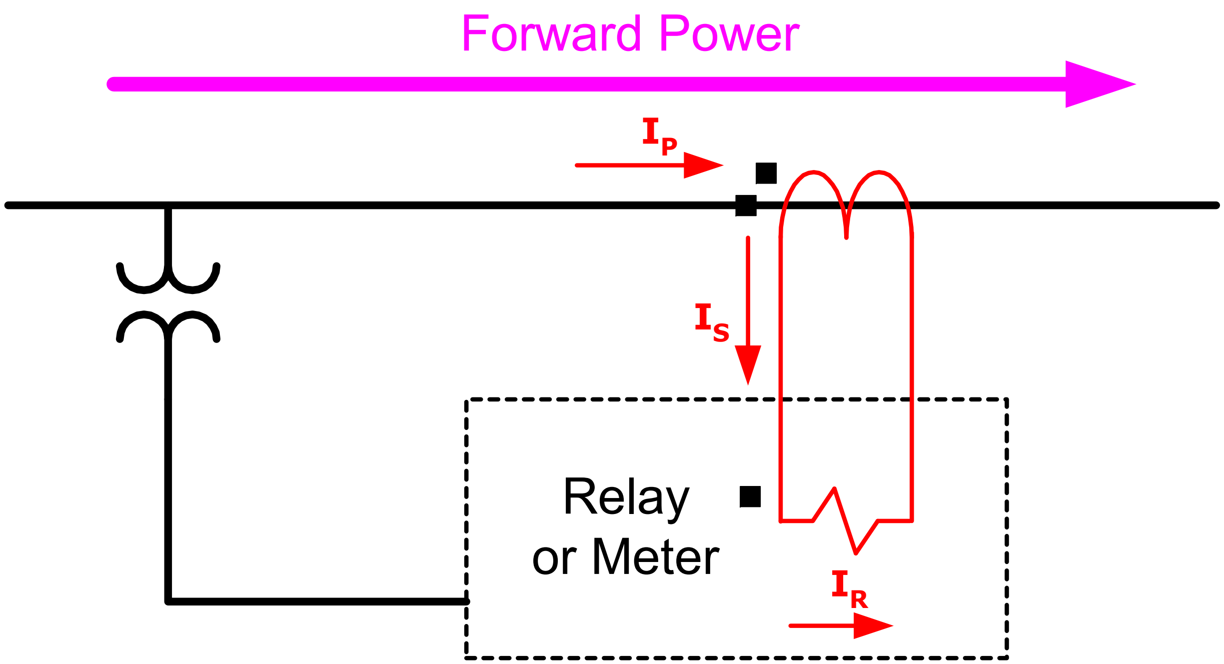
Protective Relaying Overview

Current Transformer

- Reduce Current to Manageable Levels
- Expressed In Ratio. IE, 3000:5

Protective Relaying Overview

How Does a Protective Relay Work?



Protective Relaying Overview

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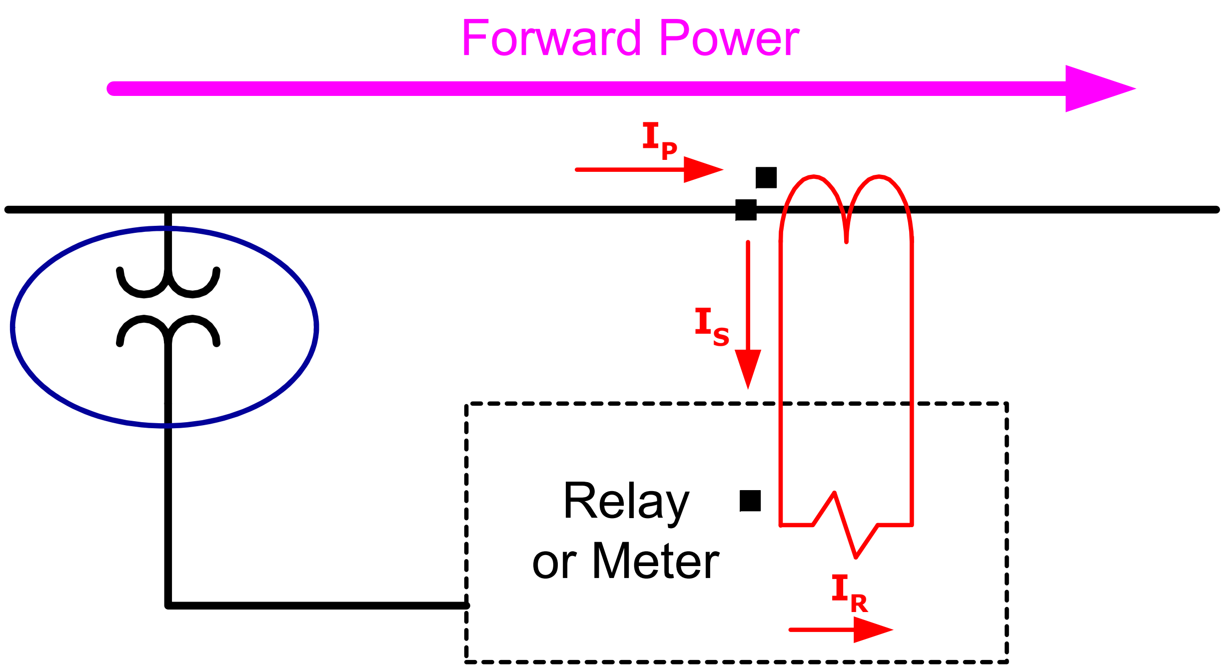

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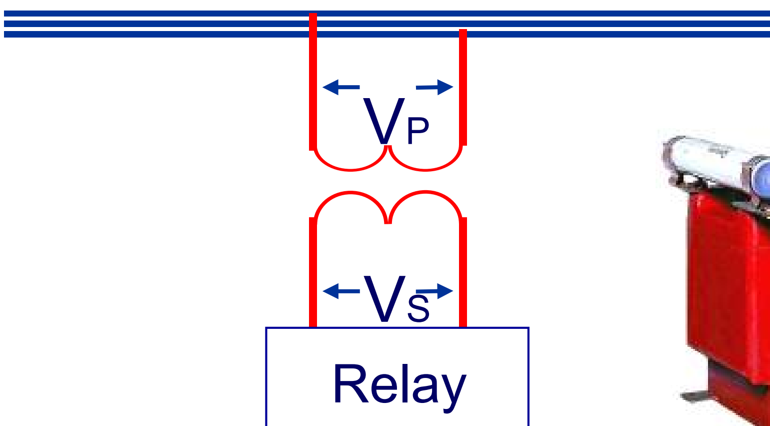
Protective Relaying Overview

Voltage Transformer

- Reduce Voltage to Manageable Levels
- Expressed In Ratio. IE, 7200:120



Protective Relaying Overview

No.	DESCRIPTION
2	Time-delay
21	Distance
25	Synchronism-check
27	Undervoltage
30	Annunciator
32	Directional power
37	Undercurrent or underpower
38	Bearing
40	Field
46	Reverse-phase
47	Phase-sequence voltage
49	Thermal
50	Instantaneous overcurrent
51	AC time overcurrent
59	Overvoltage
60	Voltage balance
63	Pressure
64	Apparatus ground
67	AC directional overcurrent
68	Blocking
69	Permissive
74	Alarm
76	DC overcurrent
78	Out-of-step
79	AC reclosing
81	Frequency
85	Carrier or pilot-wire
86	Lock out
87	Differential
94	Tripping

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Protective Relaying Overview

Questions on Basic Protective Relaying Concept?

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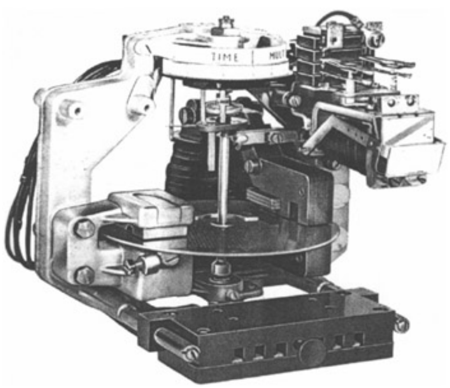
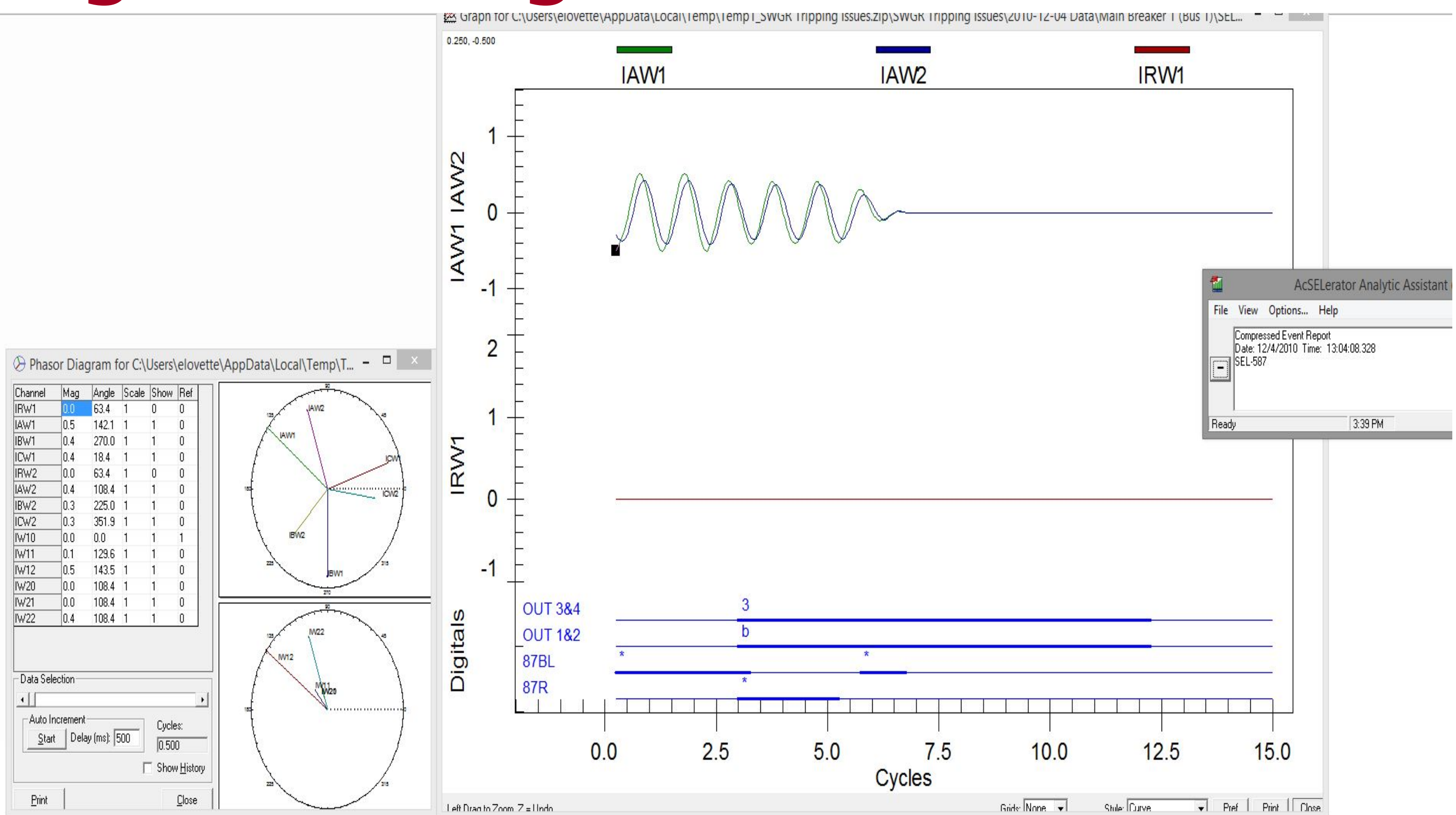
Old Style - Electromechanical



New Style – Digital

Electromechanical - Diagnostics

Digital – Diagnostics



Advantages of Digital Relays

Multifunctional	Compatibility with digital integrated systems	Low maintenance (self-supervision)
Highly sensitive, secure, and selective	Adaptive	Highly reliable (self-supervision)
Reduced burden on CTs and VTs	Programmable Versatile	Low Cost

Protective Relaying Overview

Major Brands

- Schweitzer Engineering Labs (SEL)
- Beckwith Electric
- GE Multilin
- Siemens
- Square-D SEPAM
- Cooper Power Systems / Eaton
- ABB

Protective Relaying Overview

Audience Question:

Who is using Electromechanical Relaying?

Who is using Digital Relaying?

What Brands and Why?

Case Studies

Don't be afraid to make mistakes. Be afraid of not learning from them.

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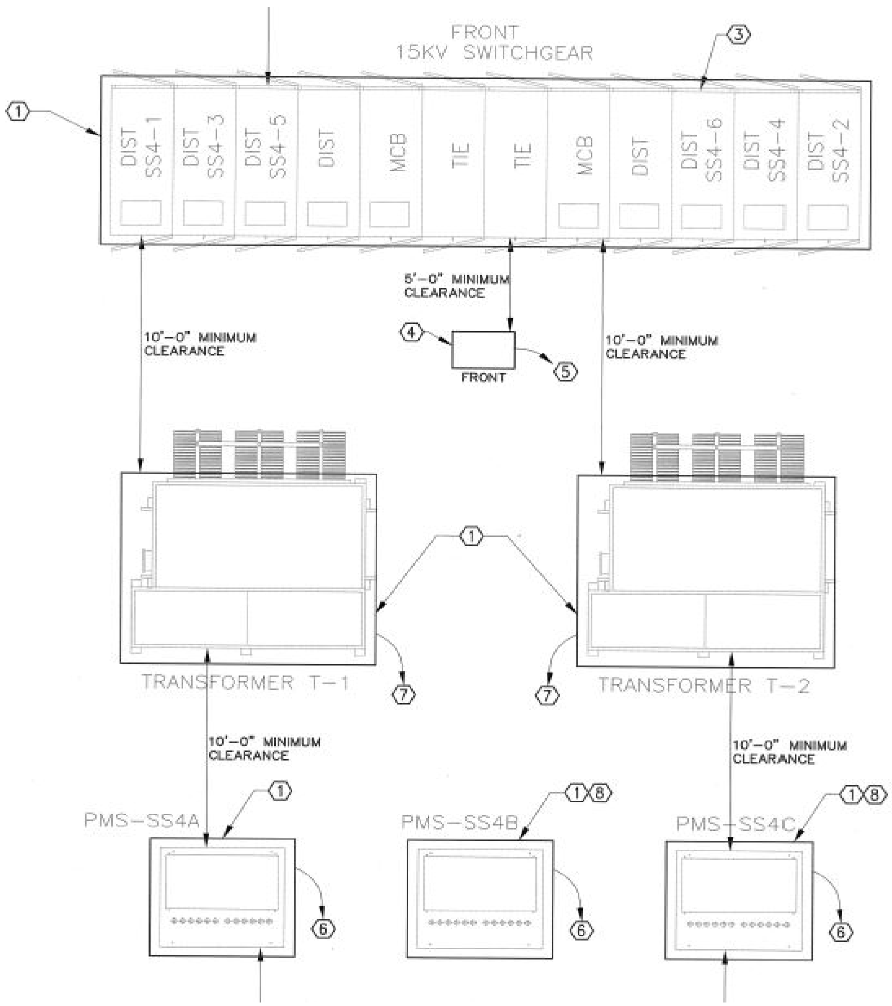
Case Study #1 – Differential



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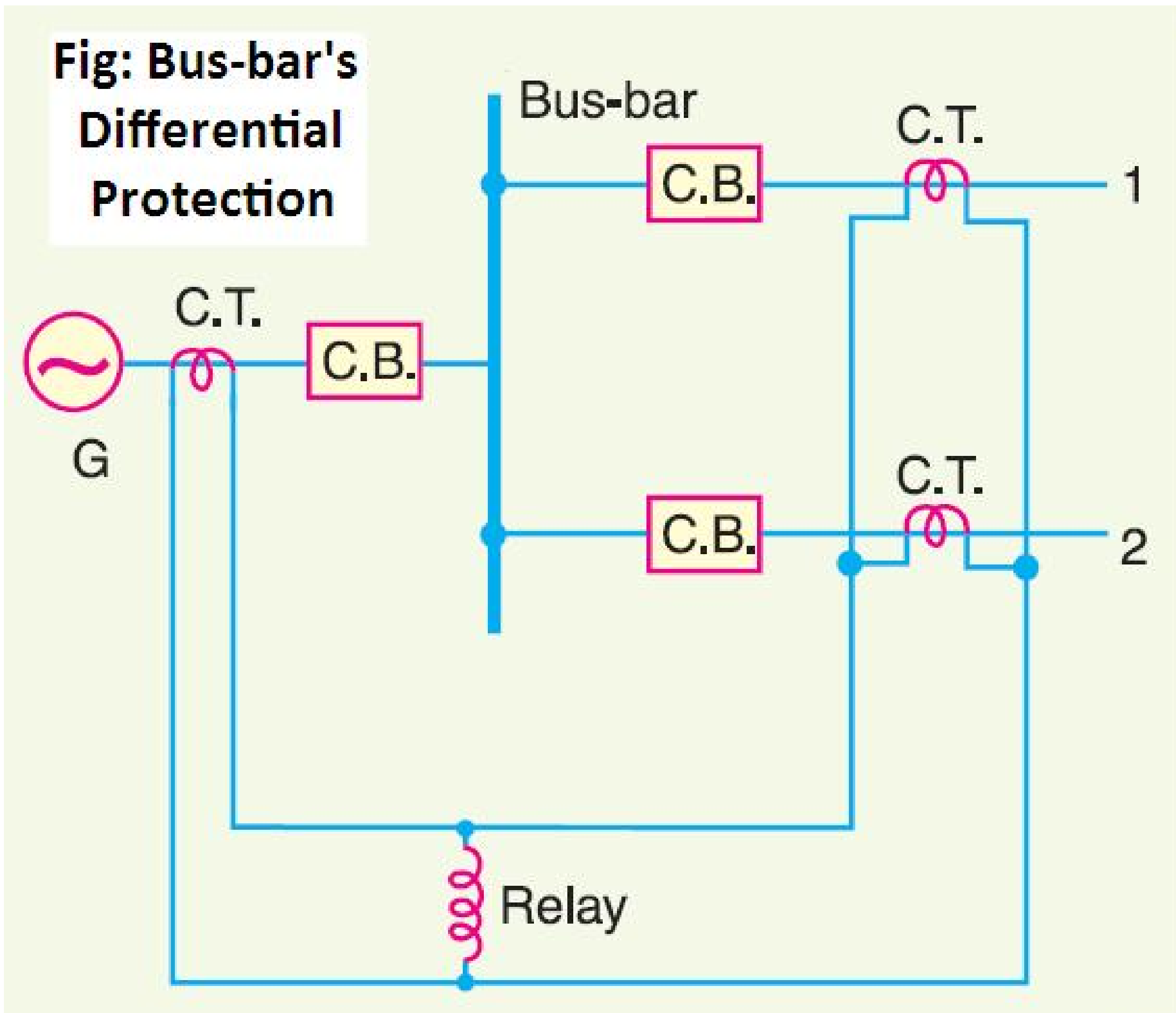
Case Study #1 – Differential

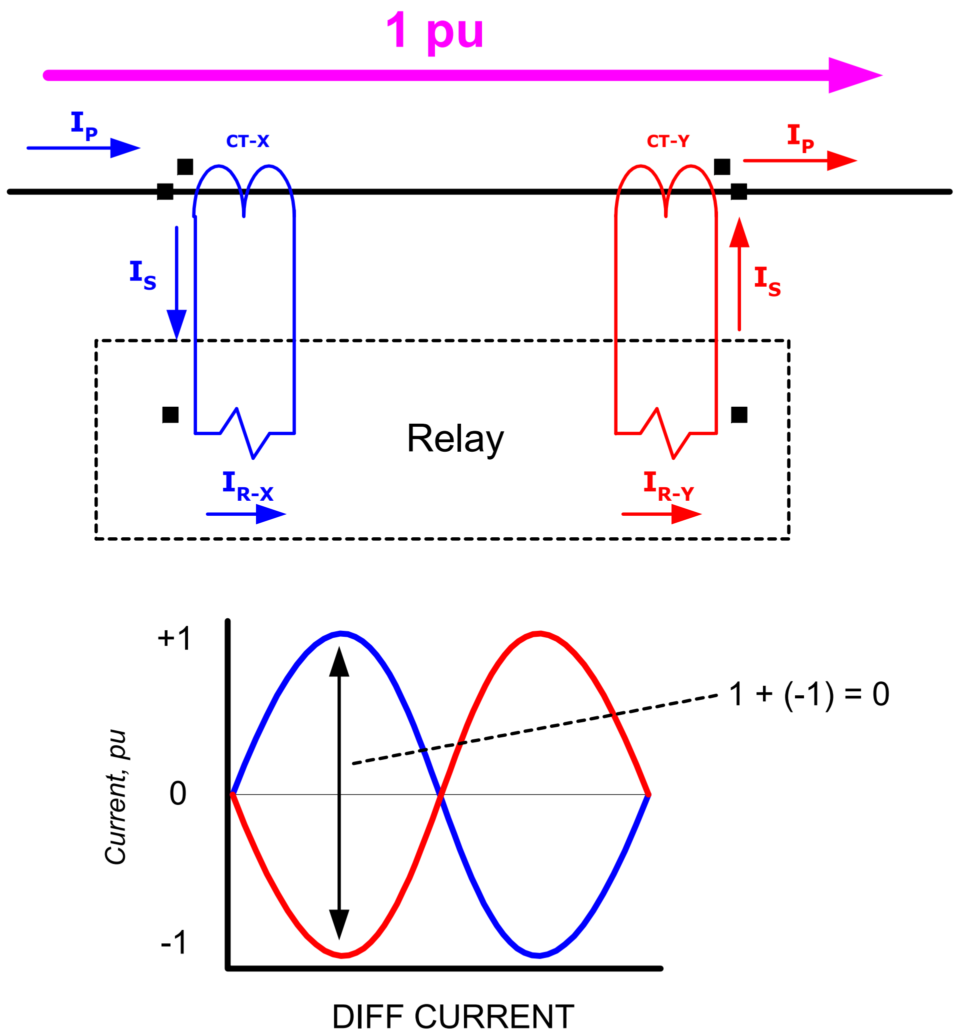
Differential Protection (87)

- Kirchhoff's Current Law (Current In = Current Out)
- Simple
- Fast

Case Study #1 – Differential



Case Study #1 – Differential



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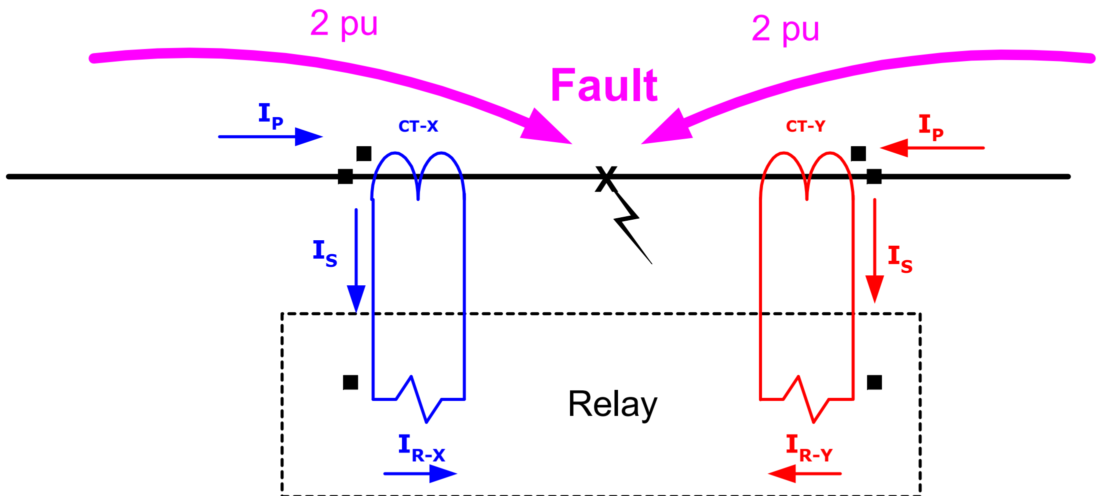
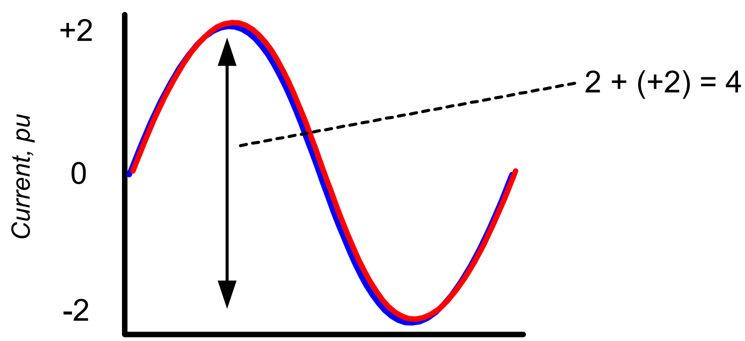
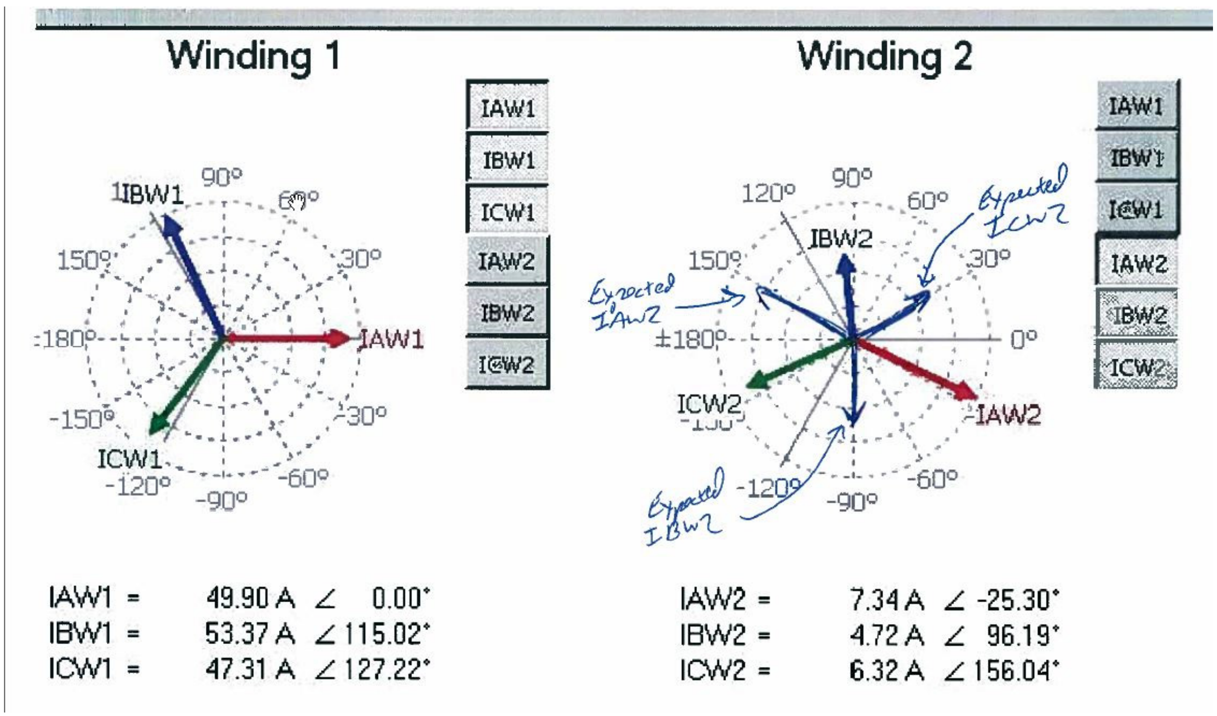




DIFF CURRENT

Case Study #1 – Differential



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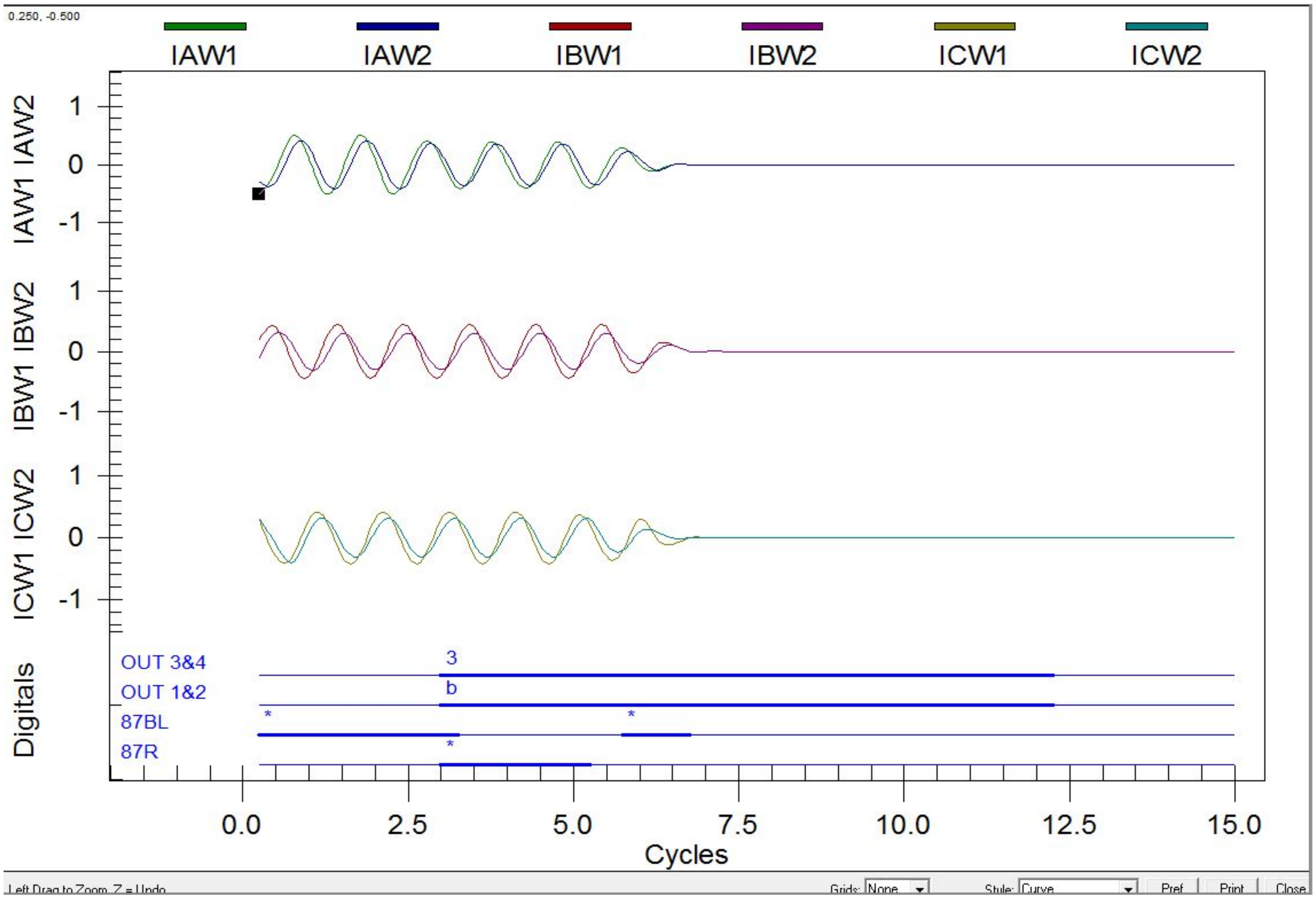

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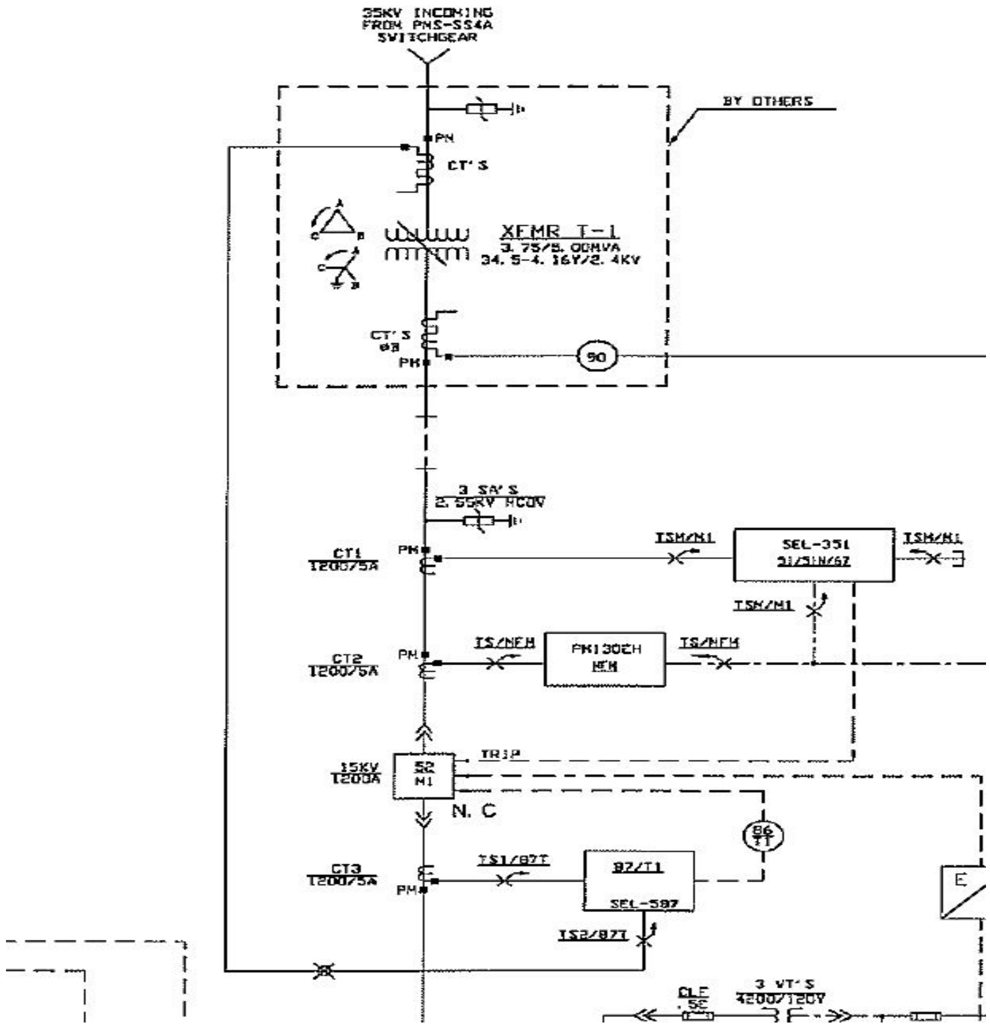
Case Study #1 – Differential



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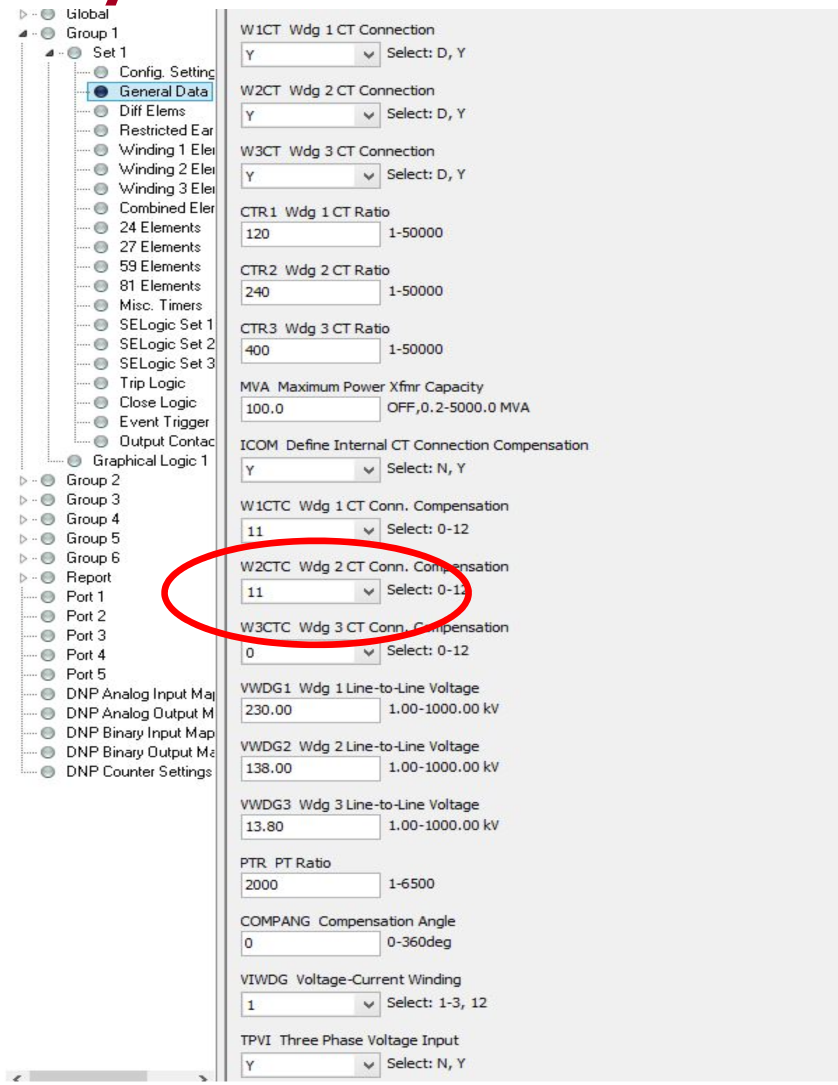
Case Study #1 – Differential

Solution

Roll the CTs

Case Study #1 – Differential



Case Study #1 – Differential

Lesson Learned

Always Validate Differential CT Orientation

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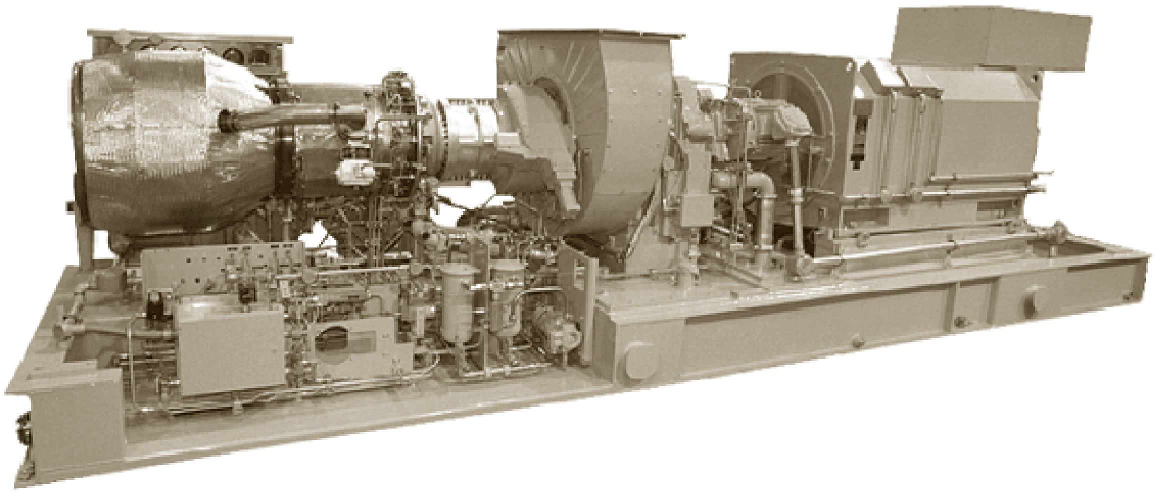
Case Study #1 – Differential

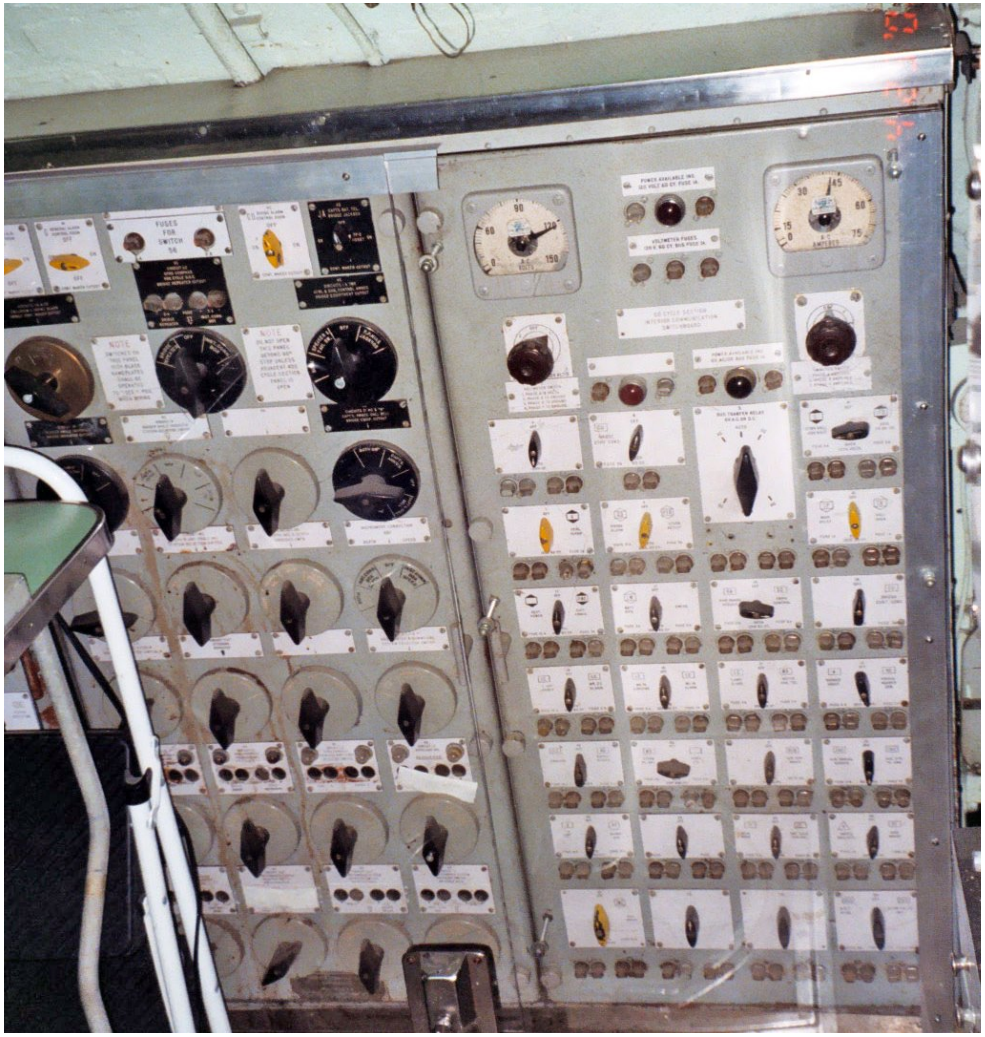
Audience Question

Ever Experienced Flipped CTs?

Case Study #2 – Sub Switches



Case Study #2 – Sub Switches



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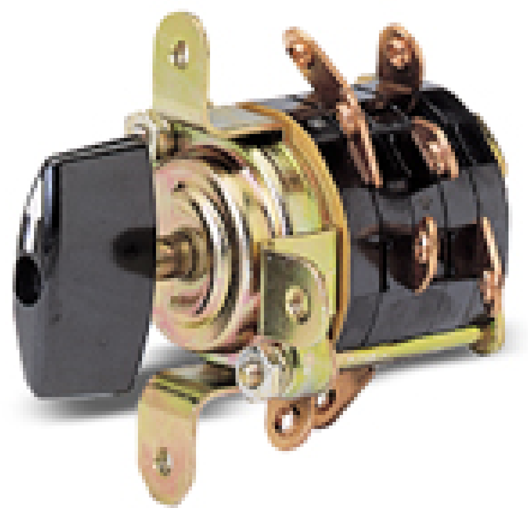

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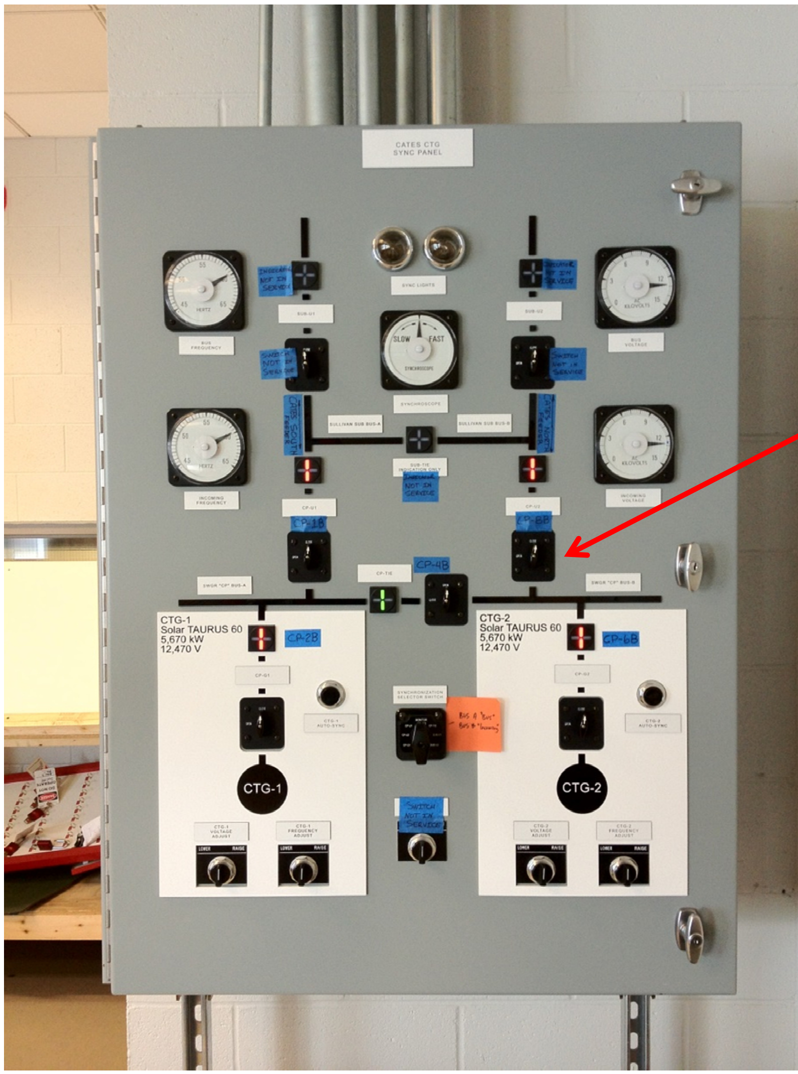

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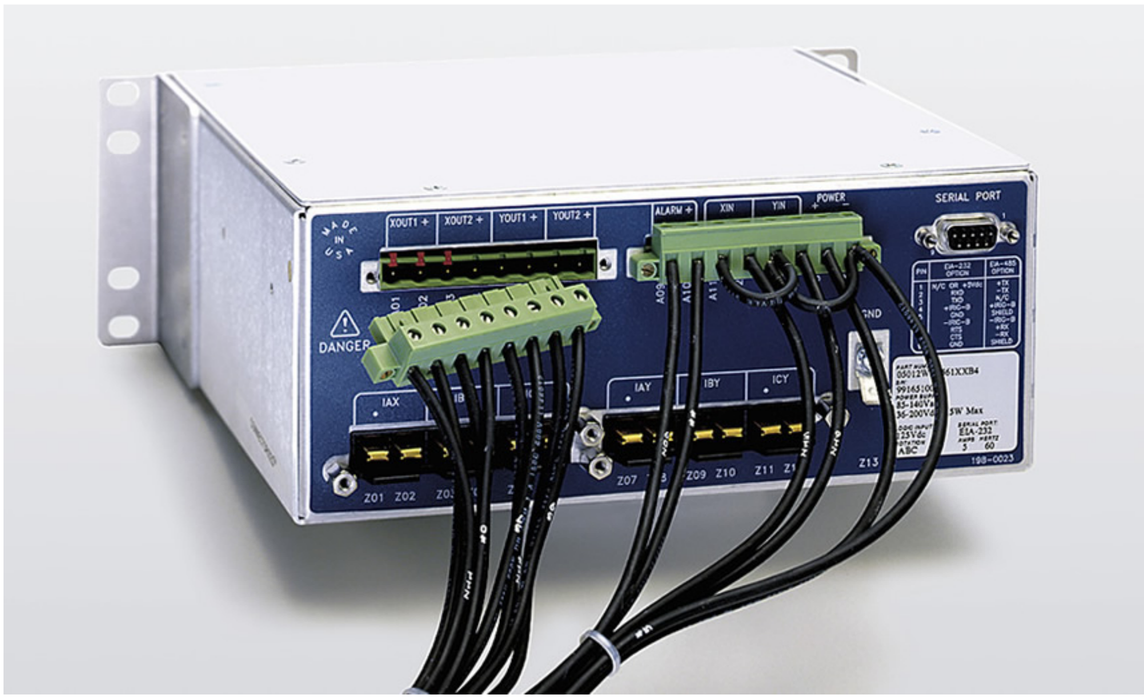

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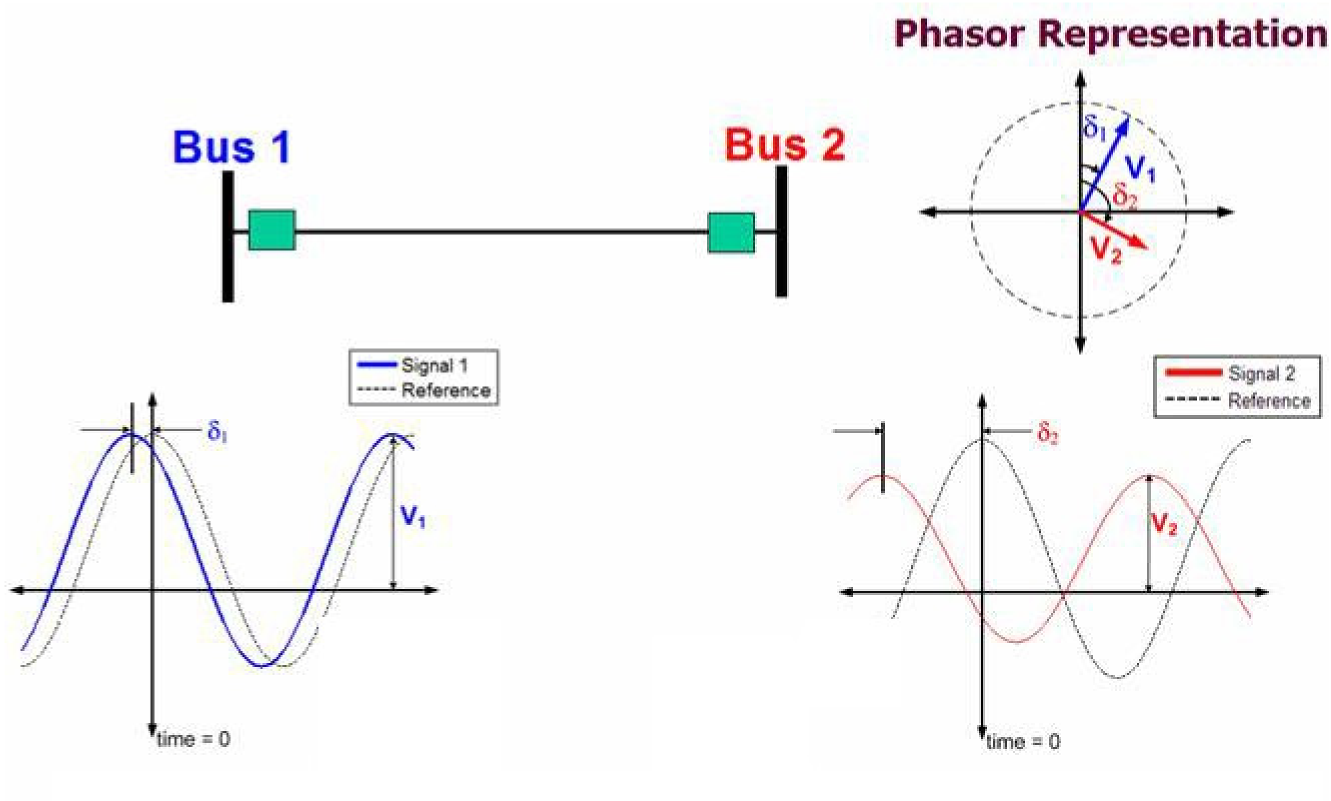
Case Study #2 – Sub Switches

Synchronization Protection (25)

- Connecting Two Independent Systems
- Phasor Comparison
  - Voltage / Phasing
  - Rate of Change

Case Study #2 – Sub Switches



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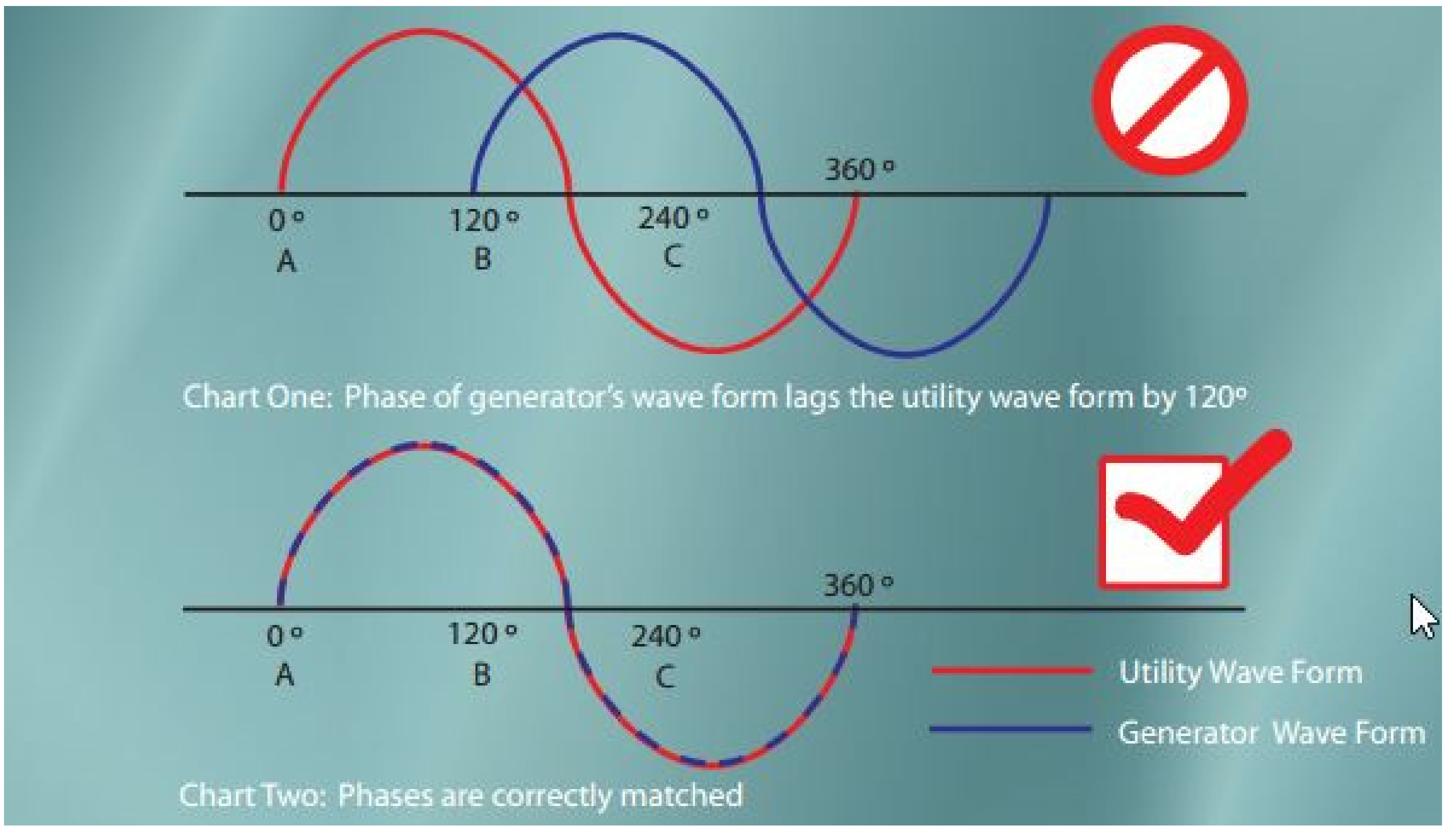

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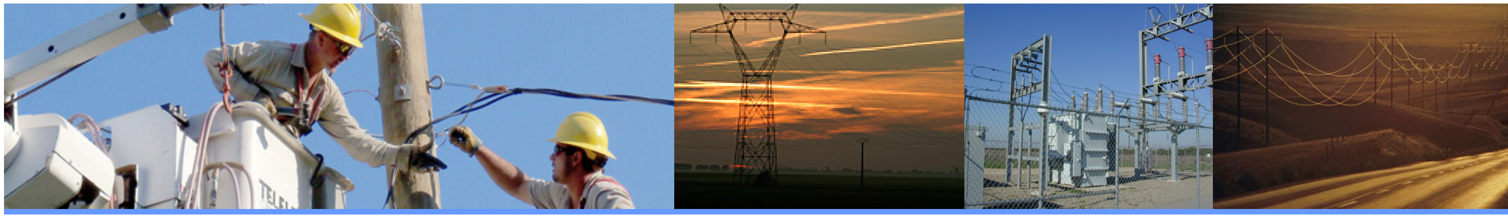

Case Study #2 – Sub Switches

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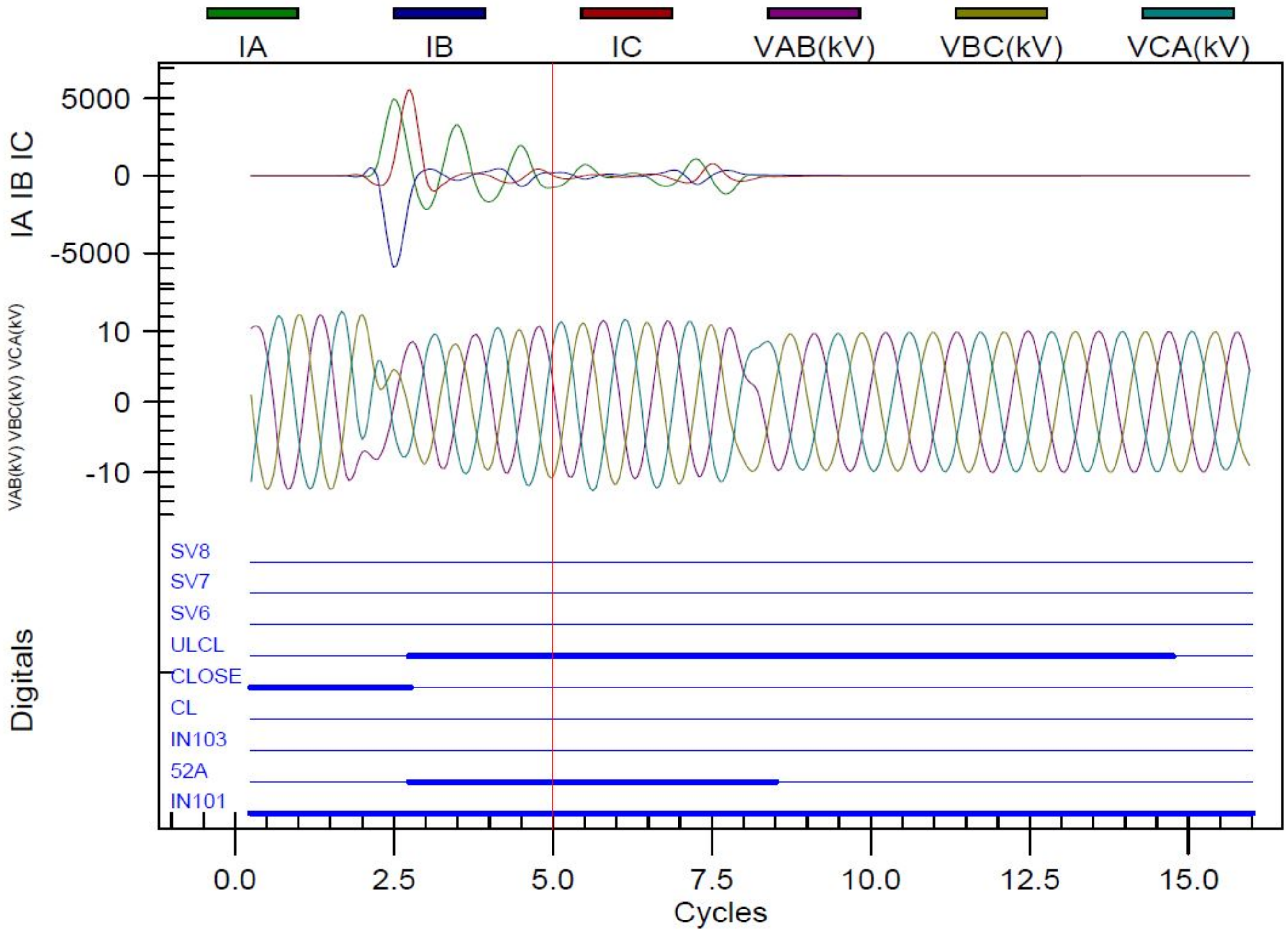
Case Study #2 – Sub Switches



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Case Study #2 – Sub Switches

Close Logic Equations

CLEN Close Enable Equation (SELogic Equation)

1

CL Close Initiate Equation (SELogic Equation)

(25A1+59PP2*27VS)*(/IN101+/IN103)

ULCL Unlatch close conditions (SELogic Equation)

TRIP+52A+!SV6+!IN103

ER Event Trigger Equation (SELogic Equation)

IN101+IN103+TRIP+CLOSE+SV7+SV8

Output Contact Equations

OUT101 Output Contact 101 (SELogic Equation)

TR2

OUT102 Output Contact 102 (SELogic Equation)

CLOSE*IN101

Close Logic Equations

CLEN Close Enable Equation (SELogic Equation)

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Output Contact Equations

OUT101 Output Contact 101 (SELogic Equation)

TR2

OUT102 Output Contact 102 (SELogic Equation)

CLOSE*IN101*SV6

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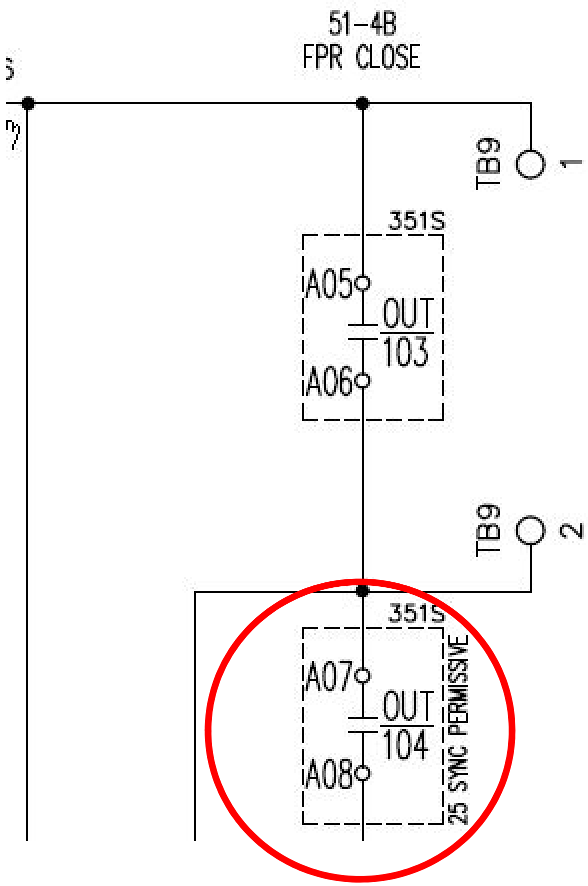
Case Study #2 – Sub Switches

Solution

Reprogram CLOSE Function

Case Study #2 – Sub Switches



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Case Study #2 – Sub Switches

Lesson Learned

Do Not Use Continuous Contact Switches in Trip / Close

Dedicated Sync (25) Contact

Case Study #2 – Sub Switches

Questions?

Case Study #3 – National Football

Audience Question

Who Likes Football?

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Case Study #3 – National Football

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Power outage causes delay

By Jane McManus | ESPNNewYork.com Updated: November 15, 2010, 11:59 AM ET

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EAST RUTHERFORD, N.J. -- Giants fullback Bear Pascoe was in the huddle on the field of the new Meadowlands Stadium in the third quarter against the Cowboys, when all of a sudden the lights went out.

"I just wondered how they were going to get them back on," said Pascoe.

The stadium was plunged into dark, the only visible light coming from the dots of cell phone screens. Everyone on the field froze and waited, Pascoe said. Six seconds later the lights were back on, along with questions about how something like a power outage could happen in the middle of a game in a brand new $1.6 billion stadium.

"It's frustrating whether its a new building or an old building," Giants co-owner John Mara said. "You certainly don't want to see anything happen like that during the game."

The CEO of the New Meadowlands Stadium, Mark Lamping, said that the problem was in a disruption to one of two feeder sources to the stadium. That caused a momentary outage at 6 p.m., at the start of the third quarter. Then when the power switched from the first to the second source of power, the longer six-second blackout occurred with 10:57 left in the third quarter. It took roughly six minutes to start play again, and there was another two minute pause while waiting for the television broadcast to resume.

More From ESPN Dallas, ESPN New York

Everything you need to know about the NFC showdown between the Giants and Cowboys can be found in the **Cowboys Center** and **Giants Center**

- Cowboys blog • Giants blog

"The appropriate diagnostics will be done," Lamping said. "We'll determine exactly what happened in conjunction with our friends from the [New Jersey Sports & Exposition Authority] and [Public Service Electric and Gas Company] and if there are any adjustments that need to be made anywhere along the line we'll make those so that we can minimize risk of this ever happening again."

Two Cowboys employees were stuck in one of the elevators as those went offline, along with the escalators. Lamping said there was no smoke or fire in the building.

Players seemed to take the blackout in stride. Offensive linesman Kareem McKenzie quipped that someone needed to pay the bill. Linebacker Clint Sintim said he was on the bench and stopped in the middle of a sentence until some lights came back up.

Case Study #3 – National Football

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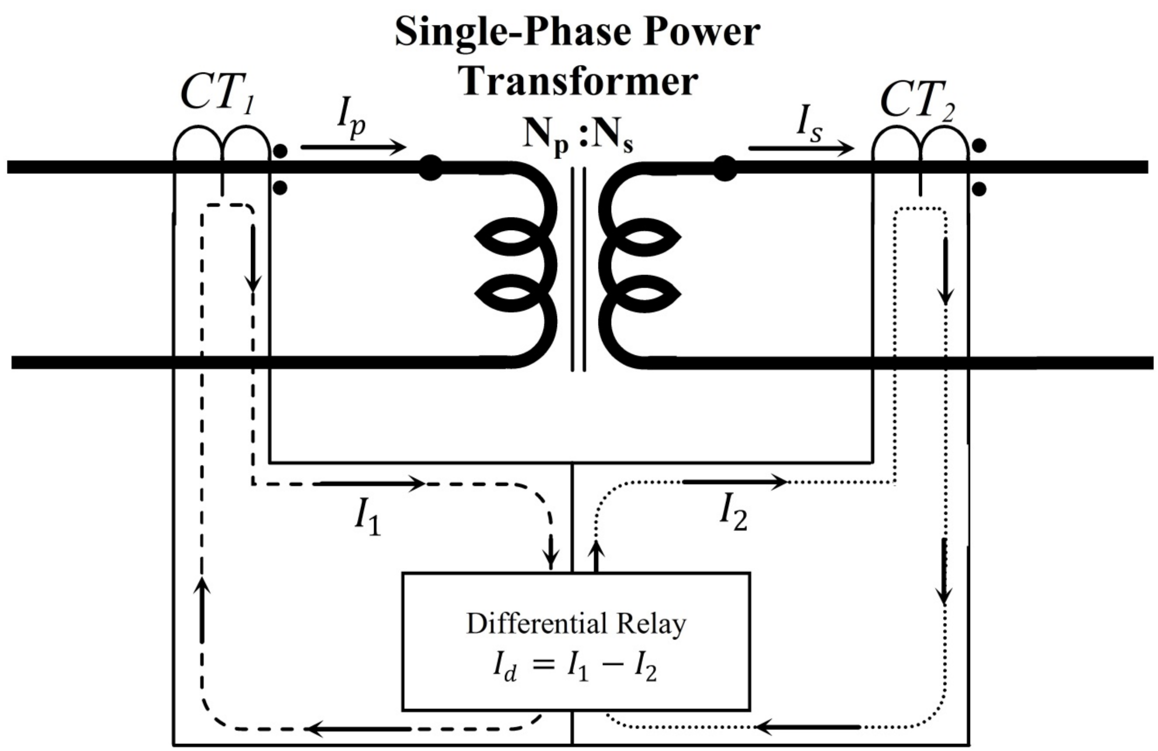
Case Study #3 – National Football



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Case Study #3 – National Football

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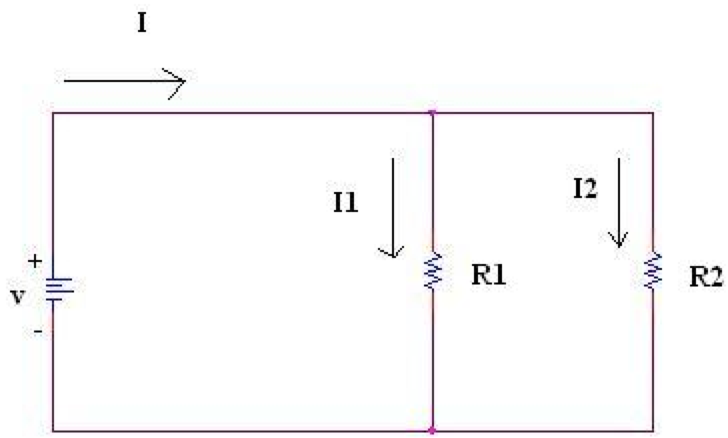

Case Study #3 – National Football

Differential Protection (87)

- Transformer in Utility Sub Tripped
- Multiple Banks / Feeds to Stadium
- All Load Transferred to 2nd Bank

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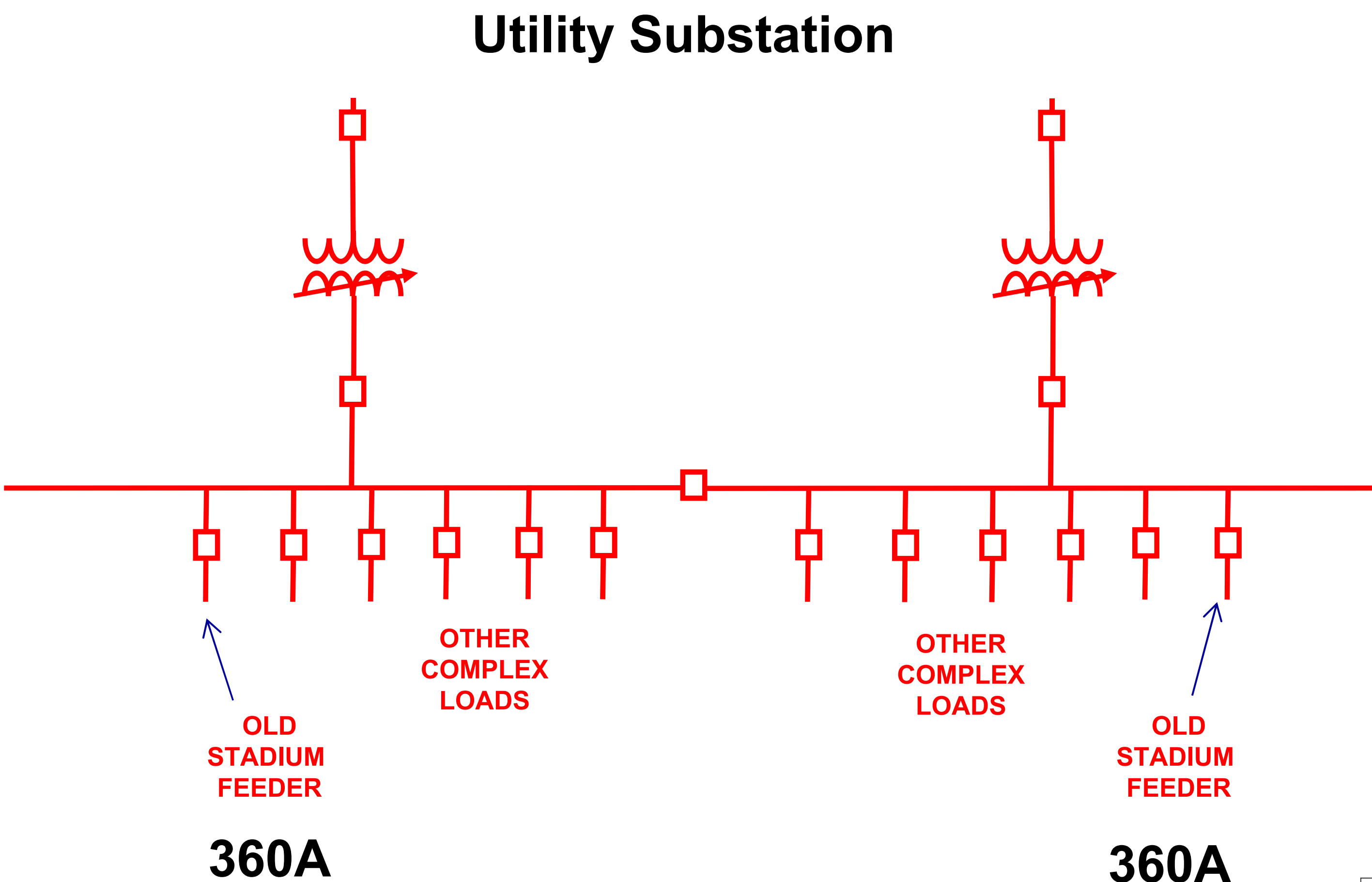
Case Study #3 – National Football



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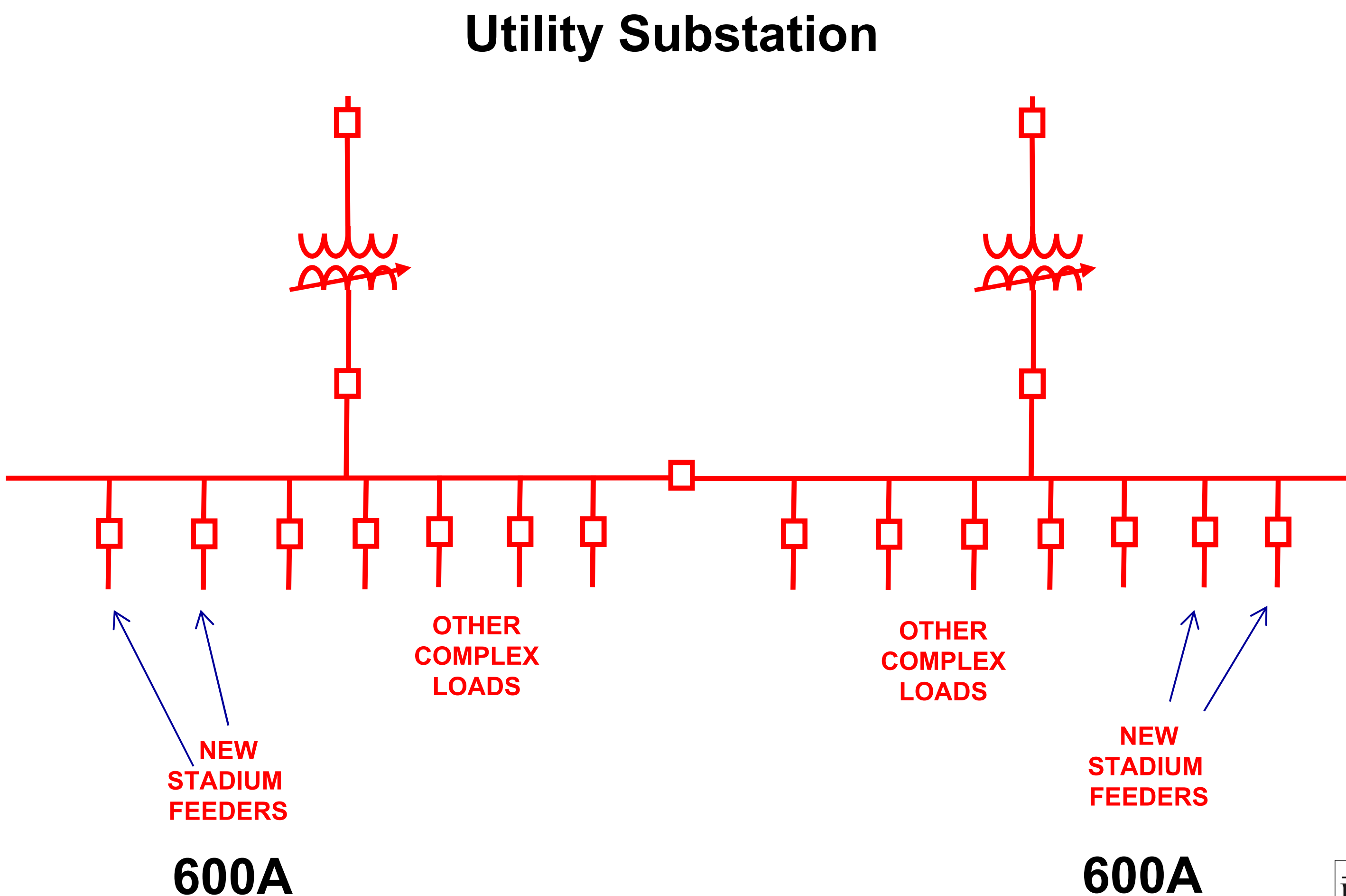

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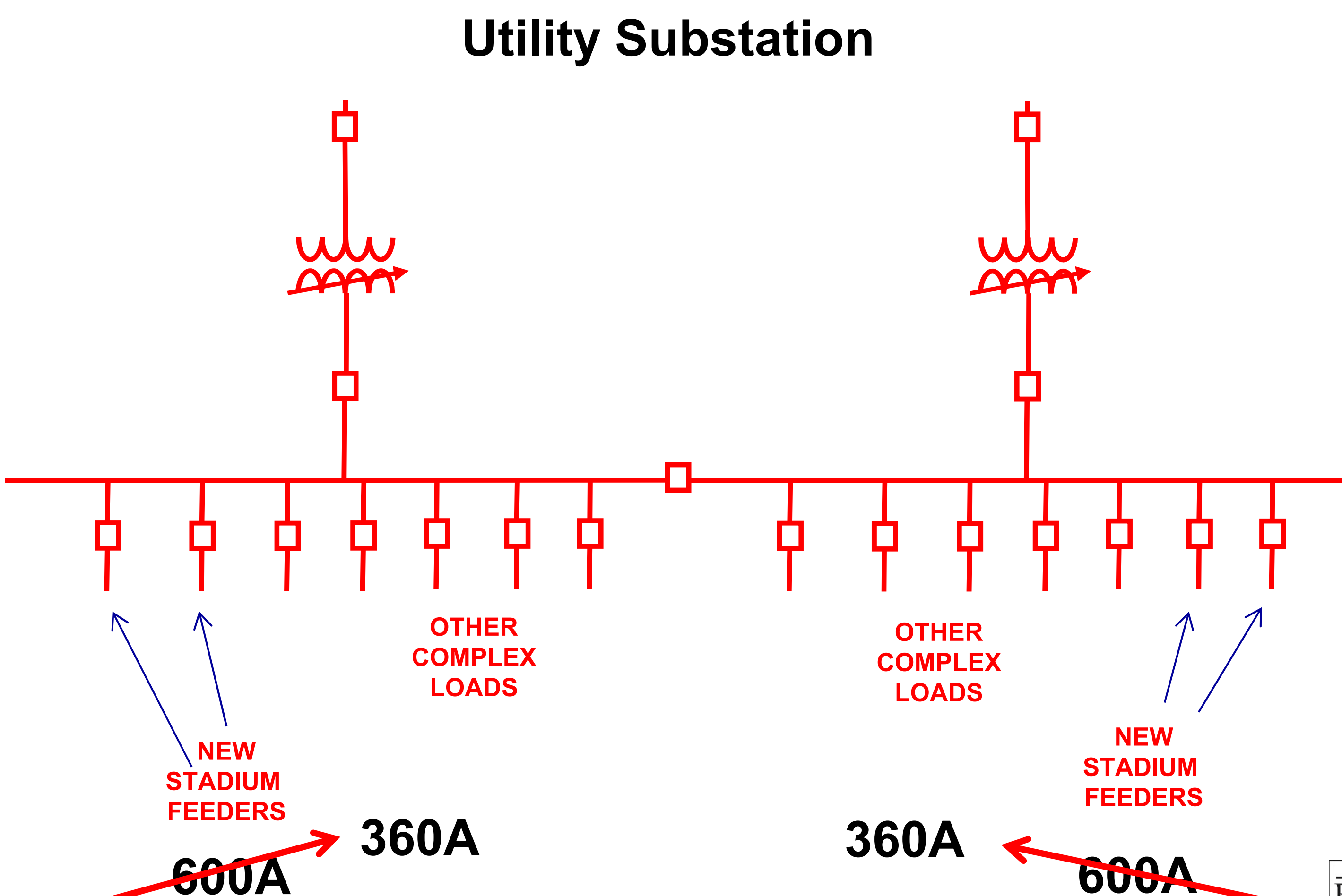
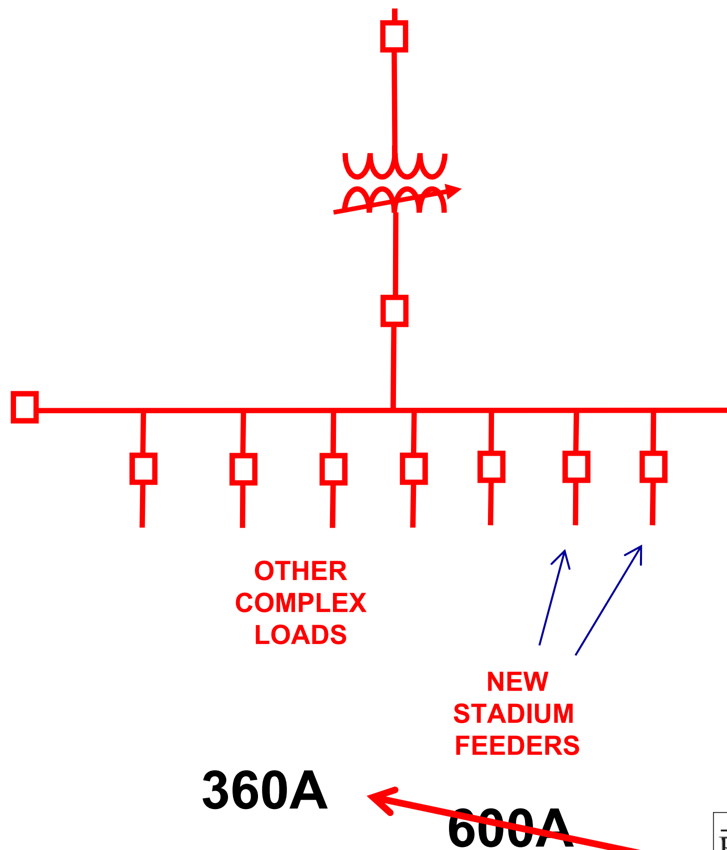


Case Study #3 – National Football

Utility Substation

- 270A Load Per Feeder
- 270A + 270A = 540A
- 540A > 360A !!



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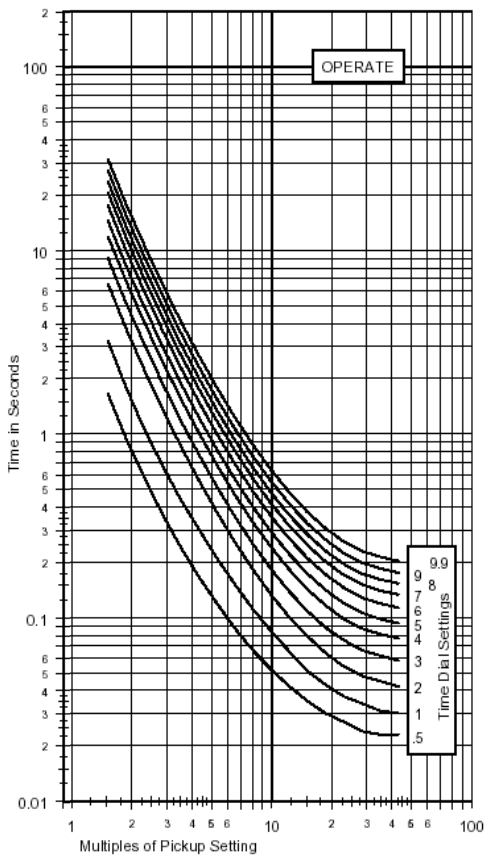
Case Study #3 – National Football

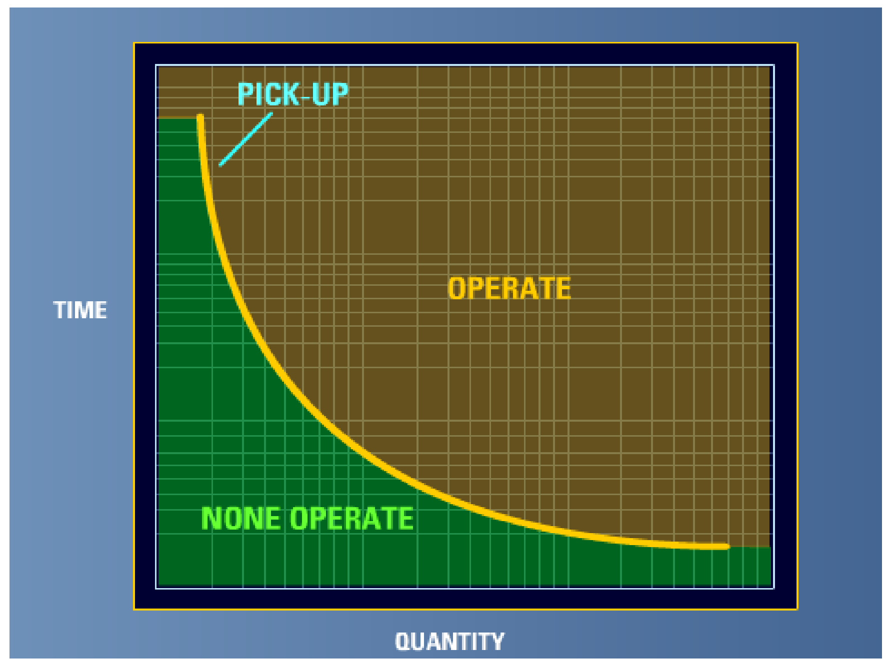
Time Overcurrent (51, 51N, 51G)

- Basic Overload Protection
- I^2 * T Curve
- Simple
- Current Only

Case Study #3 – National Football

Time Overcurrent (51, 51N, 51G)





Case Study #3 – National Football

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Case Study #3 – National Football

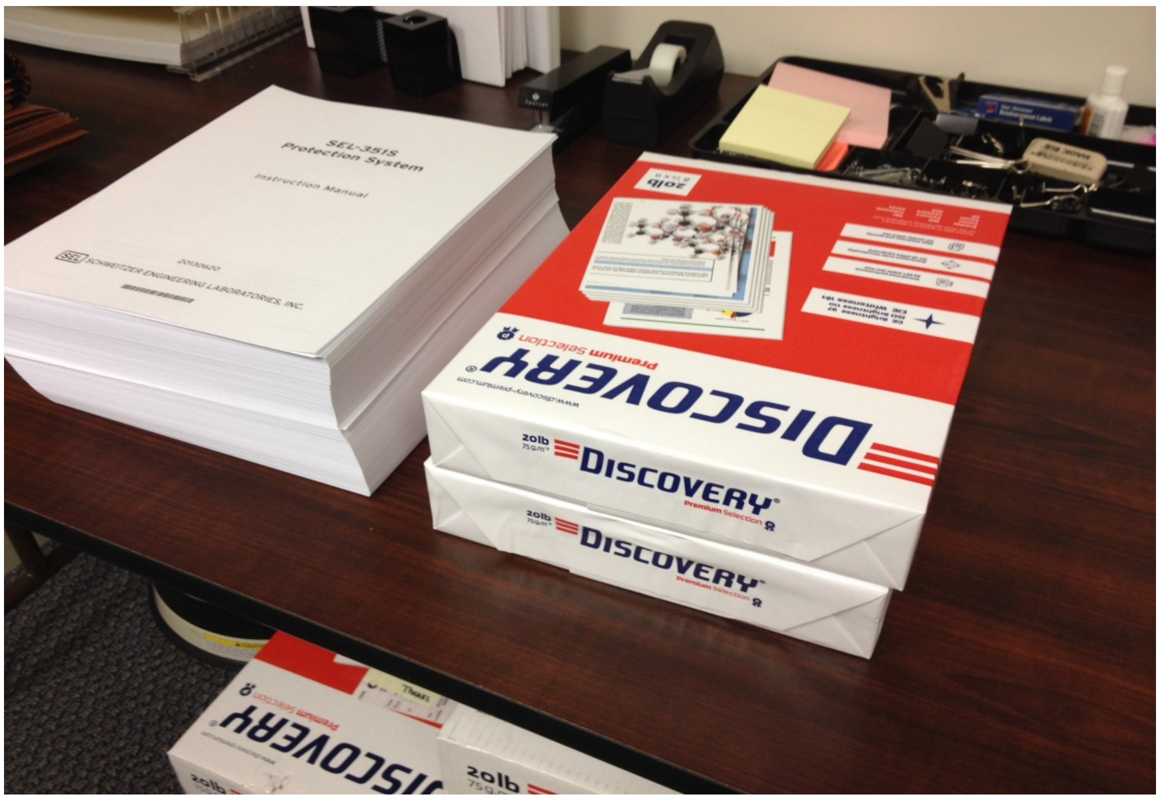
Lesson Learned

Check CT Shorting Blocks

Always QC Relay Settings

Moral of the Story

When All Else Fails, Read the Manual!



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Questions?