NOVEL APPROACH TO RELAY SETTING DEVELOPMENT

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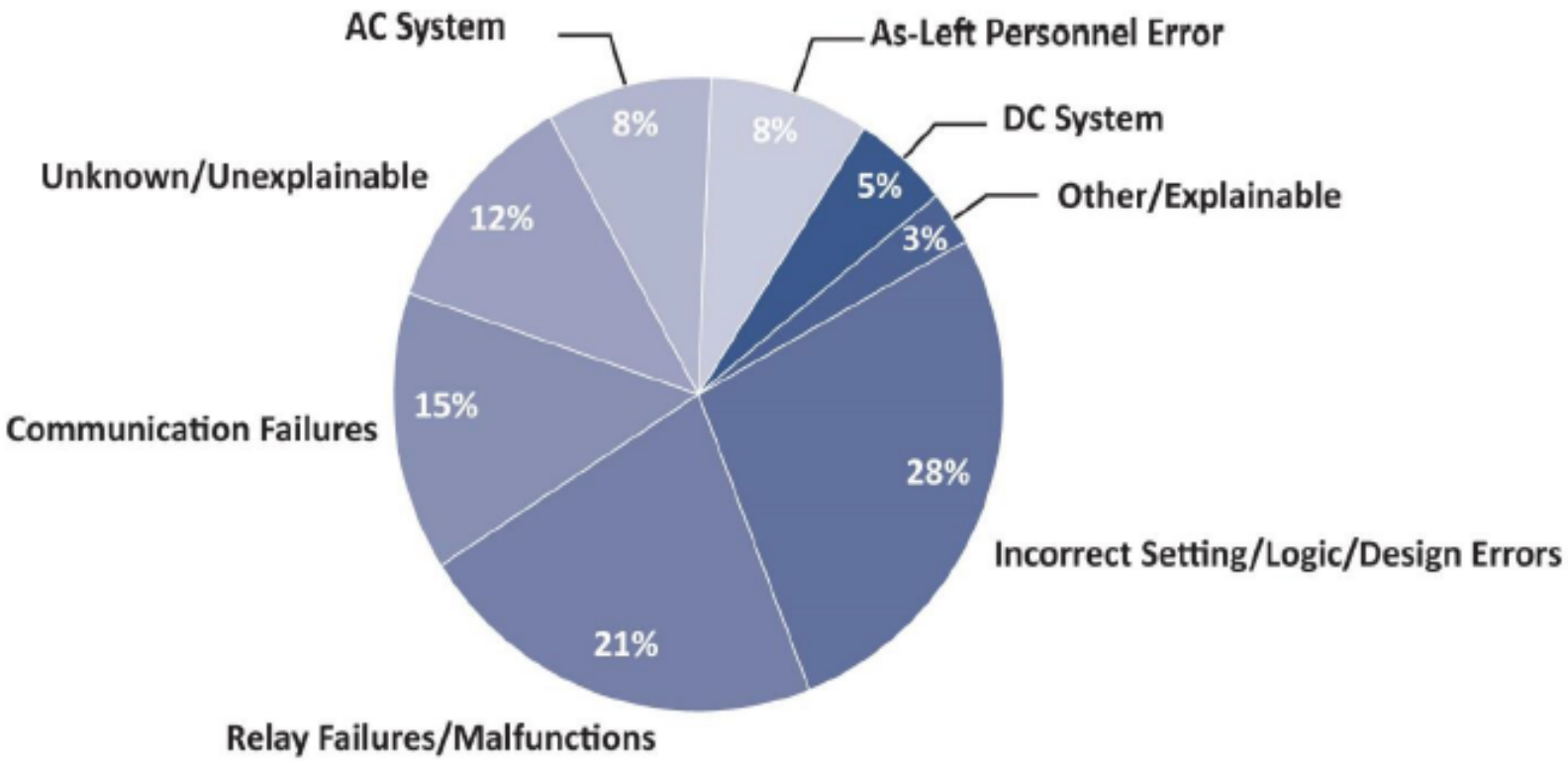
Presentation Outline

- **Introduction**
- Current Relay Setting Process
- New Approach to Relay Setting Development
- Actual Application
- Conclusion

Introduction

- Relay Settings Development
  - Has always been a long, tedious, repetitive process
  - Has always been very error prone
- Mathcad/Spreadsheets
  - Make things a little better
  - Still very long/tedious/repetitive
  - Still very error prone
- Even with today's process, over a quarter of all **relay misoperations** are due to incorrect settings or logic/design errors!

Introduction



NERC Misoperations by Cause Code (2Q 2011–3Q 2014)[55]

Introduction

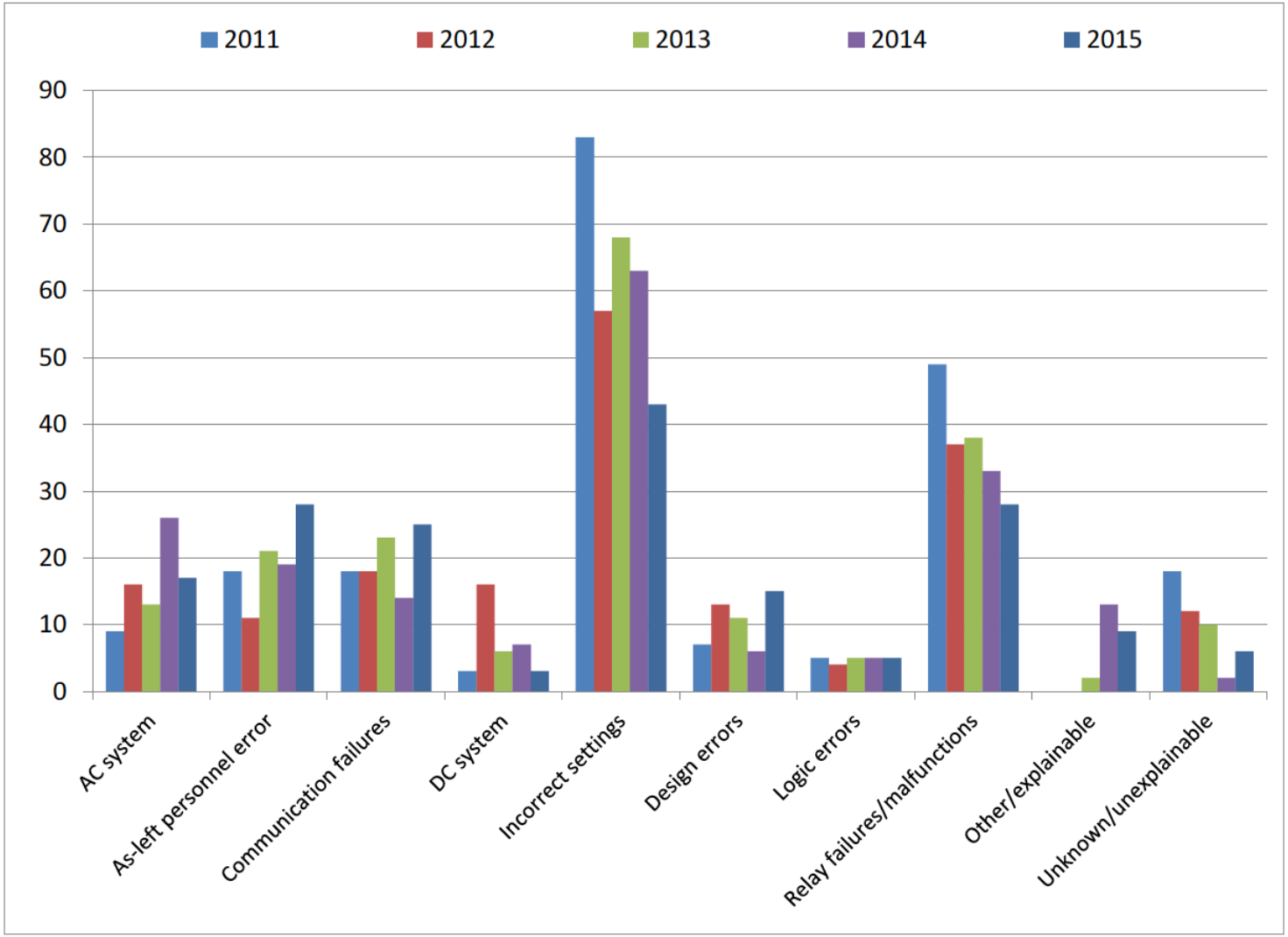


Figure 65 – Protection System Misoperations by Cause 2011-2015

Introduction

- A Novel Approach could achieve…
  - Simplicity through Automation
    - Faster
    - Easier
    - Less error-prone

- Let’s take a look at where we are now, and where we could be if we used a novel approach to relay setting development

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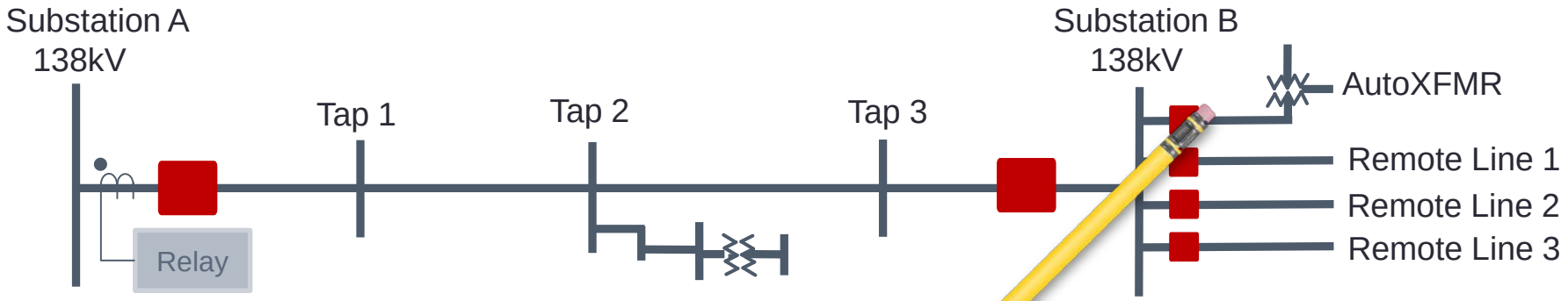
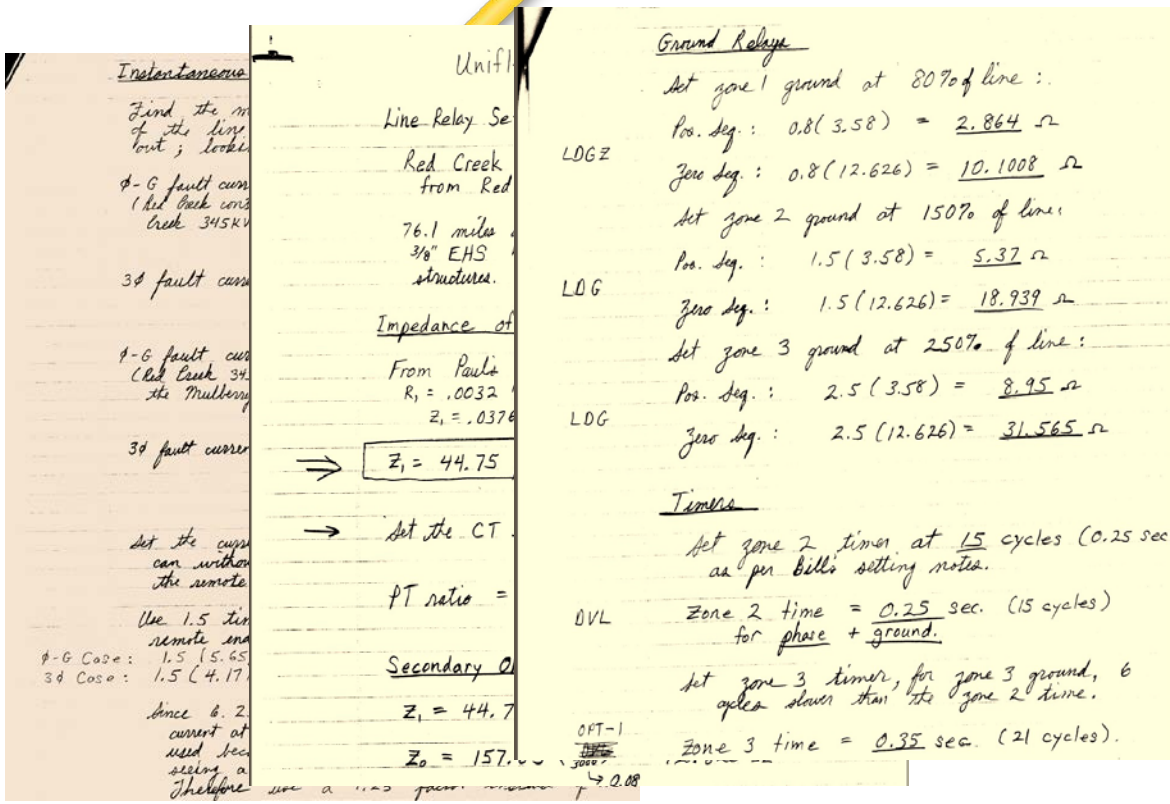
Relay Setting Development Process

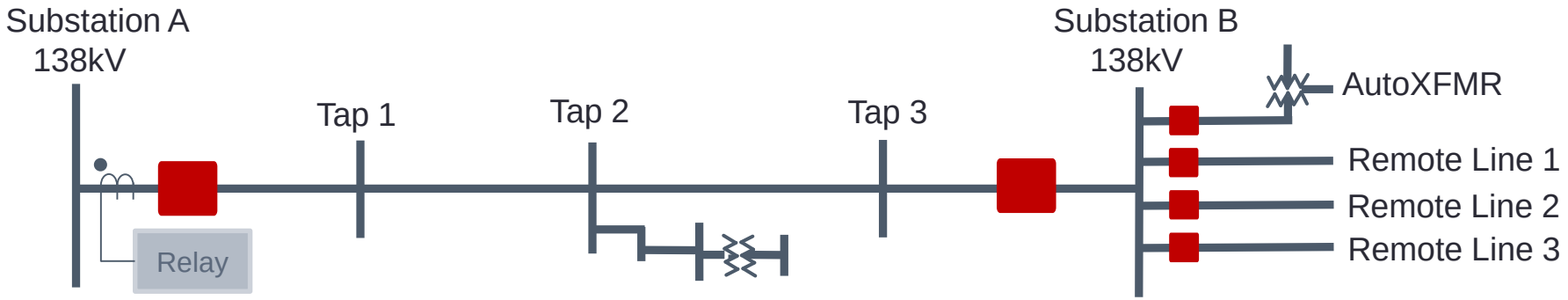


Early Days

- Paper and Pencil:
  - Build setting equations
  - Perform fault analysis
  - Scan drawings
  - Error-prone
  - Days of work



Relay Setting Development Process

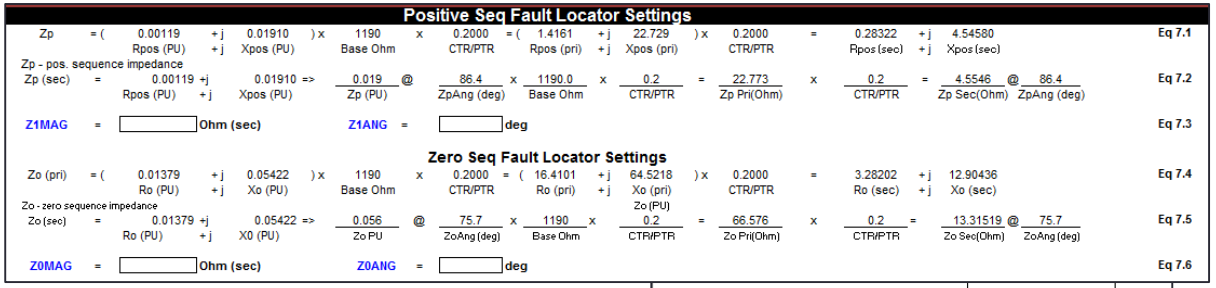


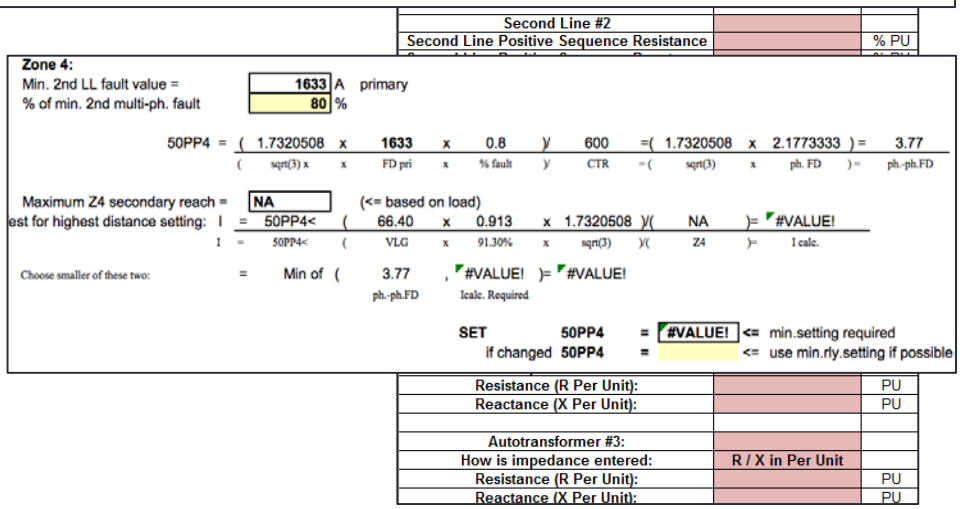
Today

- Spreadsheets or Mathcad:
  - Build setting equations
  - Paper trail and documentation
  - Copy / Paste
  - Still very error-prone
  - At least a day of work

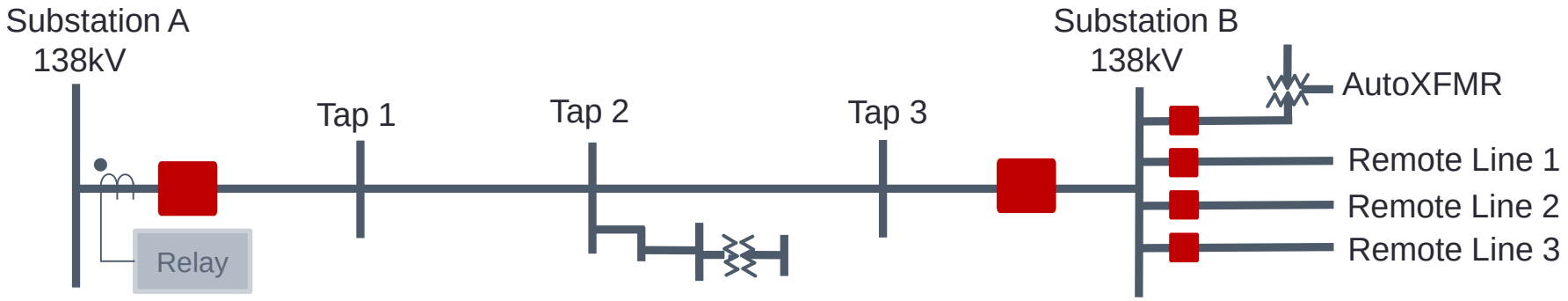
Semi-automation

Different philosophy per engineer



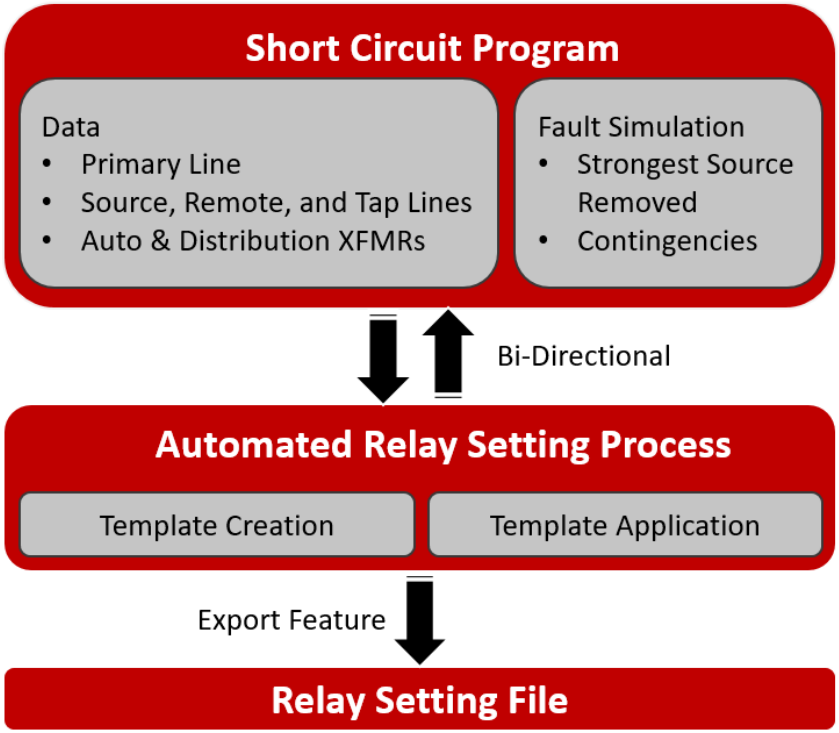


Relay Setting Development Process



Future

- Setting Automation Software:
  - Revolutionary level of efficiency
  - No manual data transfer or calculations
  - No data transfer errors
  - Automatic:
    - Fault simulations
    - Data retrieval
    - Data processing
    - Export to relay setting file



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Novel Approach To Relay Setting Development

- Okay, I’m listening… but how would this even work?
  - **Template Creation**
    - Define an arbitrary set of equations representing the intent of the protection philosophy
  - **Template Application**
    - Invoke previously defined template on any line within the grid
    - Equations drive transparent, bi-directional interaction with the short circuit program, automatically performing data collection and fault analysis

Novel Approach – Template Creation

- Setting equations must be built in a generic format
- Create equations using predefined variables:

  ✓**PL_{Z1Mag}, BaseOhms,**
  ✓**CTR, PTR,**
  ✓**SLR (Shortest Remote Line)**
  ✓**LRL (Longest Remote Line)**
  ✓**Z1P, Z1MG, 50P1P**
  ✓**Etc**

Z2P X

Zone 2 Phase Distance Reach

$$A = 1.2 \cdot PL_{Z1Mag} \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right)$$

$$B = (PL_{Z1Mag} + 0.9 \cdot 0.85 \cdot SRL_{Z1Mag}) \cdot BaseOhm$$

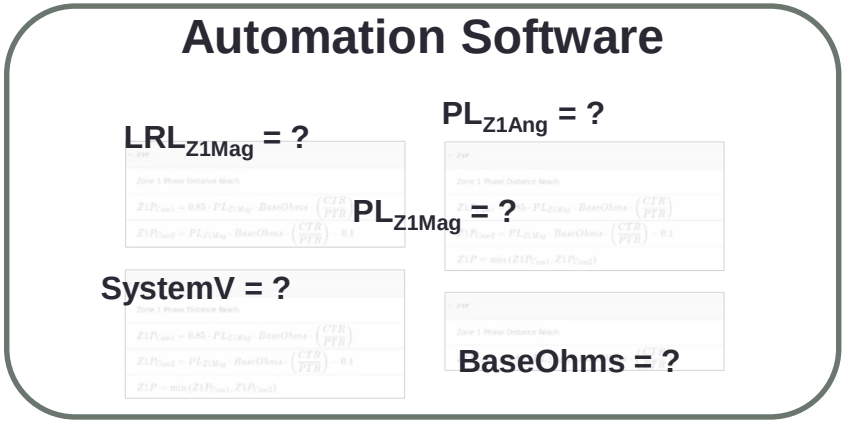
$$Z2P = \begin{cases} A, & \text{if } B < A \\ B, & \text{otherwise} \end{cases}$$

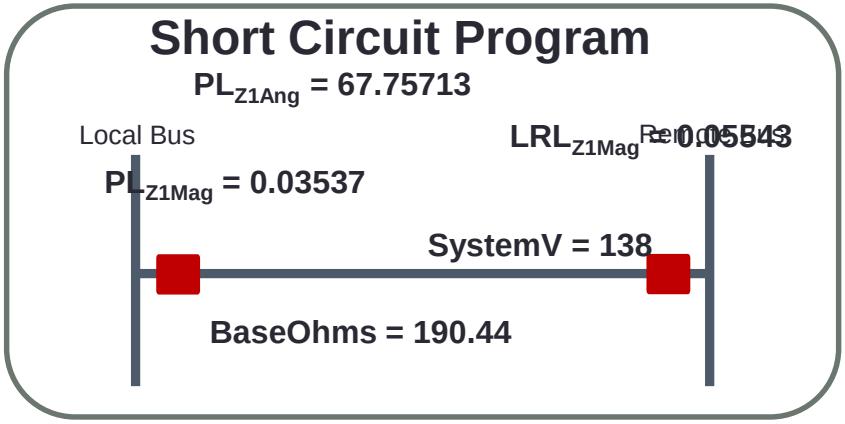
- Variables can be applied to any line application
- Variables will be automatically processed during template application

Novel Approach – Template Application

- Two Easy Steps
  - Load a short circuit program file and define the line you're working on
  - Define a few project-specific parameters (desired CTR, PTR, Load Limit, etc)
- From here, everything else is automated

Novel Approach – Template Application

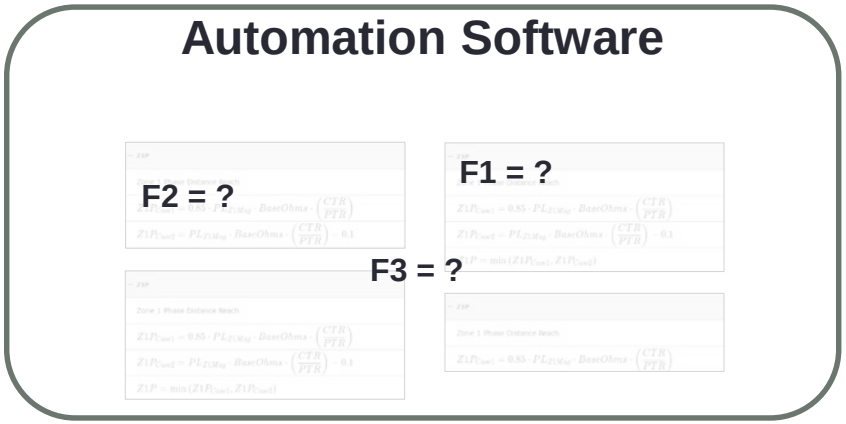


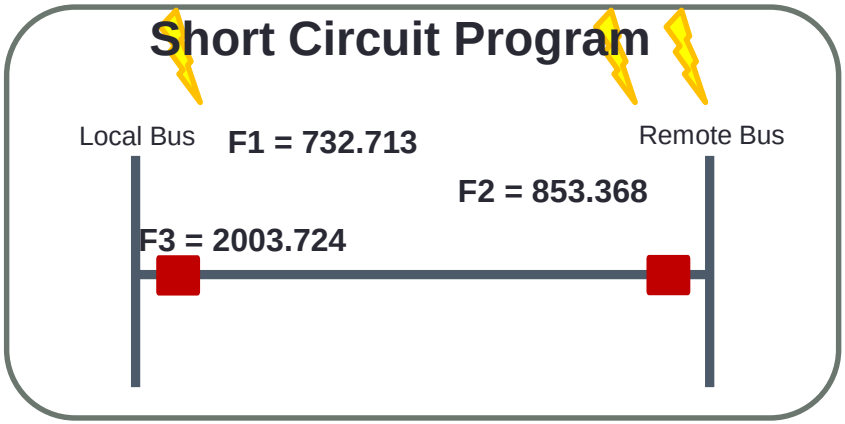


From here, everything else is automated:

- A call is made to the short circuit program to calculate and retrieve all generic values used in your philosophy template (PL_{Z1Mag}, etc)

Novel Approach – Template Application





From here, everything else is automated:

- A call is made to the short circuit program to calculate and retrieve all generic values used in your philosophy template (PL_{Z1Mag}, etc)
- A call is also made to simulate any faults needed
- The generally defined equations get automatically populated with the values retrieved
  - No need for hand calculations
  - No need for manual transfer of data

Novel Approach – Summary

- Line data values have been automatically retrieved
- Fault values with contingencies have been automatically performed
- Line data and fault data have been automatically entered into equations
- Settings have been calculated!
- The user may look over the results
- Tweak anything deemed necessary
- Automatically generate a PDF/Word report
- **And export directly to the relay setting file**

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Actual Application

- A Setting Automation Program would make things:
  - Faster
  - Easier
  - Efficient
- But an Automation Program would also make things **BETTER!**

Actual Application

For Example, let's look at a Zone 2 Setting

- Some use:
  - $Z2P = 1.2 * PL_{Z1Mag}$
  - This is OK, but could be **improved**
- Some use the maximum of:
  - $Z2P = 1.2 * PL_{Z1Mag}$
  - $Z2P = PL_{Z1Mag} + 0.5 * SRL_{Z1Mag}$
  - This makes things a little better, but it's still far from perfect

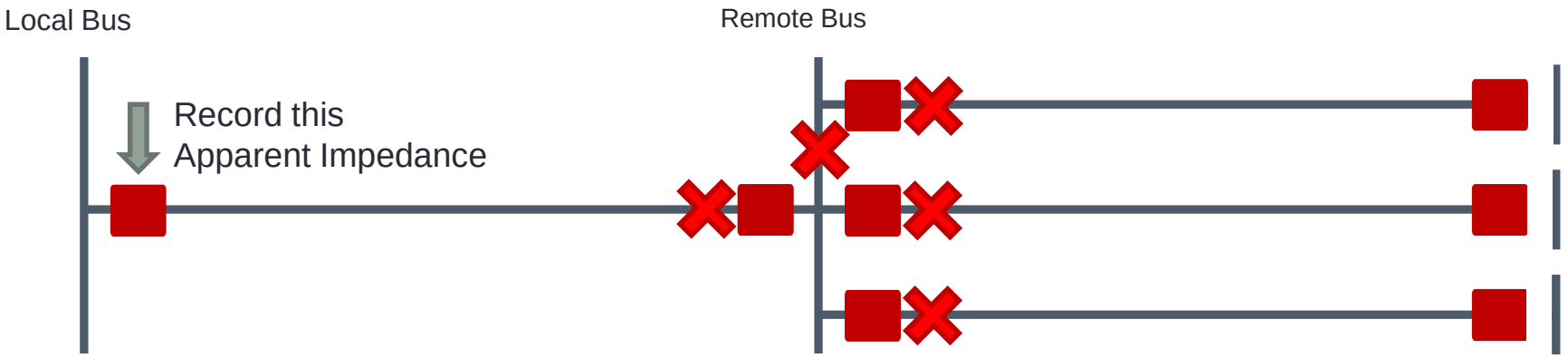
Actual Application

Most utilities use a simplified philosophy

- But why not use a more sophisticated philosophy?
  - The short answer: With current methods, **it's not practical.**
    - A simplistic philosophy works OK, and usually tweaking reaches/timers, though laborious and painstaking, will get things to coordinate properly, eventually
    - To get much more sophisticated, it would require increasingly more simulations, contingencies, checks, etc (combinatorial problem).
    - With conventional methods, more complexity = more errors.
      It's not practical.
- But a novel approach can make it worth it because all necessary steps are still completely automatable

Actual Application

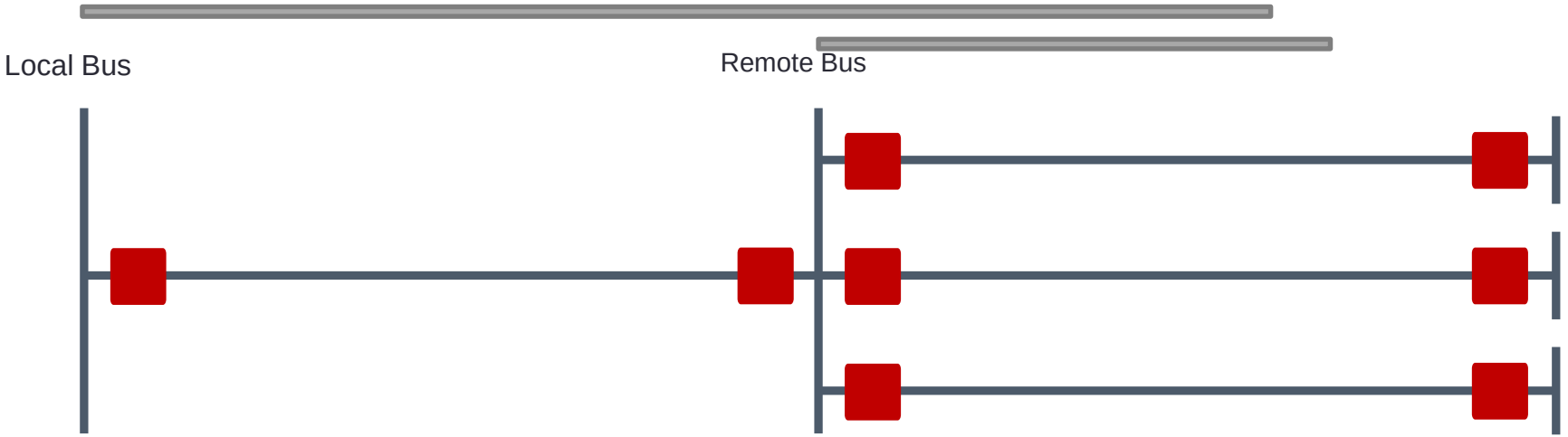
- As an introduction, the idea for a perfect **Zone 1** Setting is doable, but much simpler with an automation solution
  - The minimum of the following will be the Zone 1 Setting:
    - 0.85 * Z_{app} //Zapp of a Primary Line End Fault
    - 0.85 * Z_{app} //Zapp of a Primary Line Remote Bus Fault
    - 0.85 * Z_{app} //Zapp of the minimum Remote Line Close In Fault
    - 0.85 * Z_{app} //Zapp of the minimum Remote Line Close In End Opened Fault



Actual Application

For Zone 2 however, an automation solution is necessary

- One example of an ideal Zone 2 Reach that needs automation is to reach just before the minimum Remote Zone 1 Reach
  - To find the minimum Remote Zone 1 Reach, we have to look at each remote line, and several contingencies must be applied along with many different types of faults

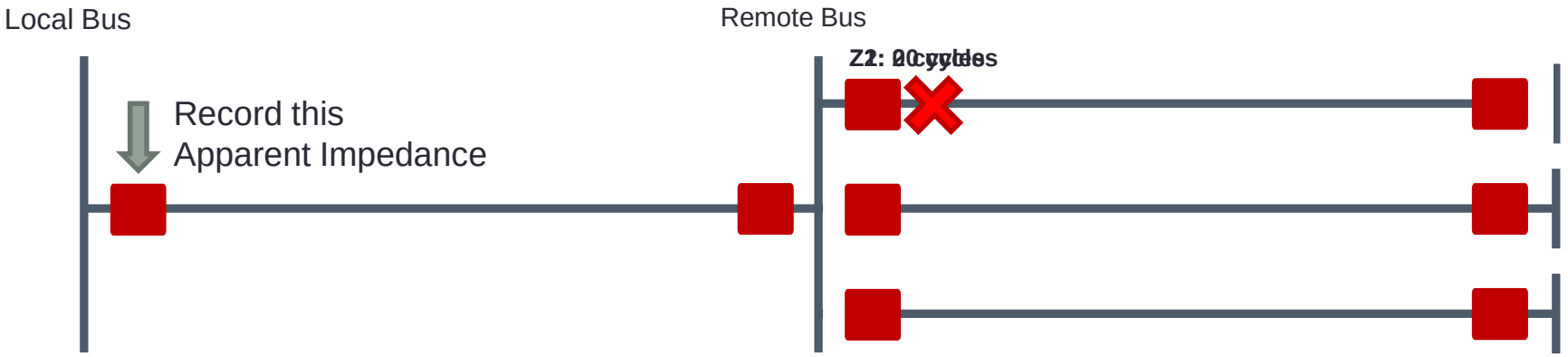


Actual Application

For Zone 2 however, an automation solution is necessary

1st Case:

- Take all remote lines out of service except one
- Do a sequenced intermediate fault with end opened on the remote line in order to find the Remote Zone 1 Reach
- Record the Apparent Impedance at the primary line local relay
- Repeat for each remote line and find the minimum Apparent Impedance

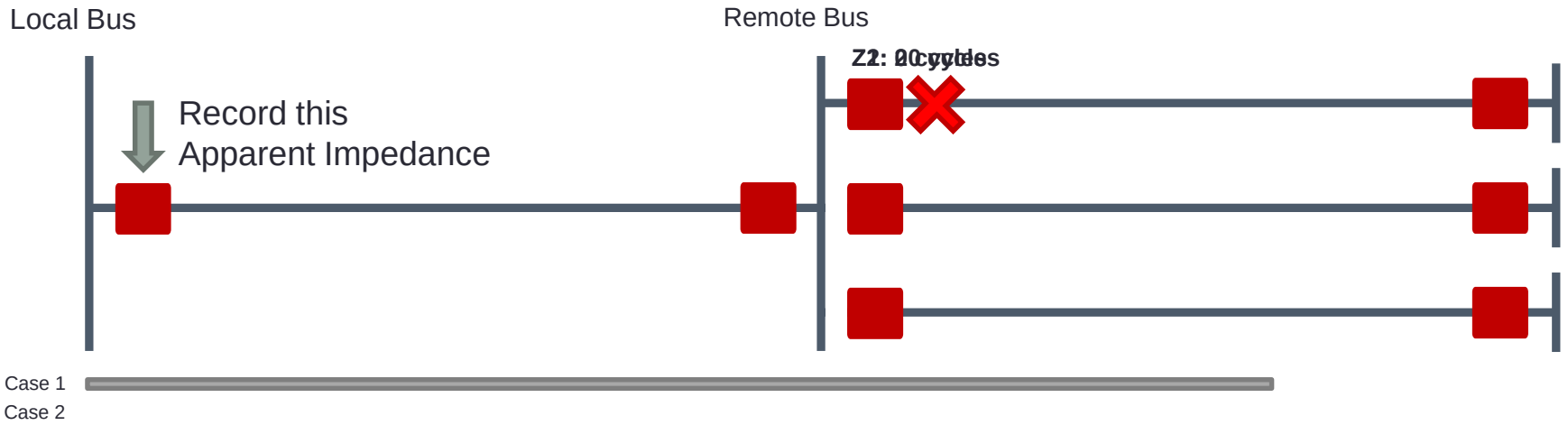


Actual Application

For Zone 2 however, an automation solution is necessary

2nd Case:

- Repeat the entire process, this time with Intermediate **End-Closed** Faults

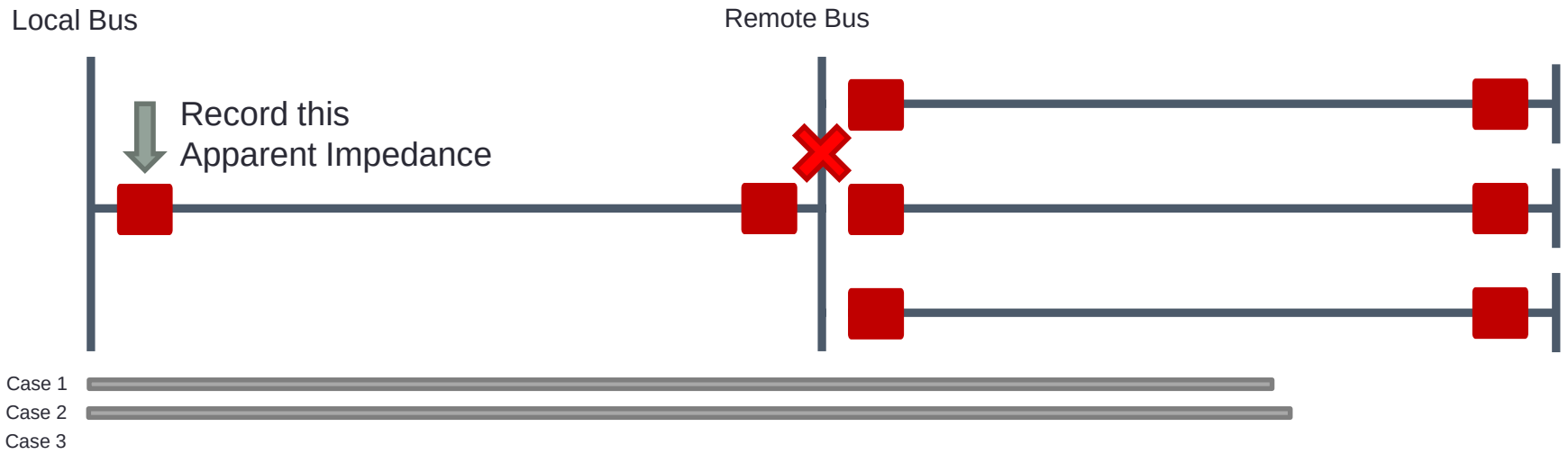


Actual Application

For Zone 2 however, an automation solution is necessary

3rd Case:

- Take all remote lines out of service
- Do a Remote Bus Fault
- Record the Apparent Impedance at the primary line local relay
- (Nothing to repeat)

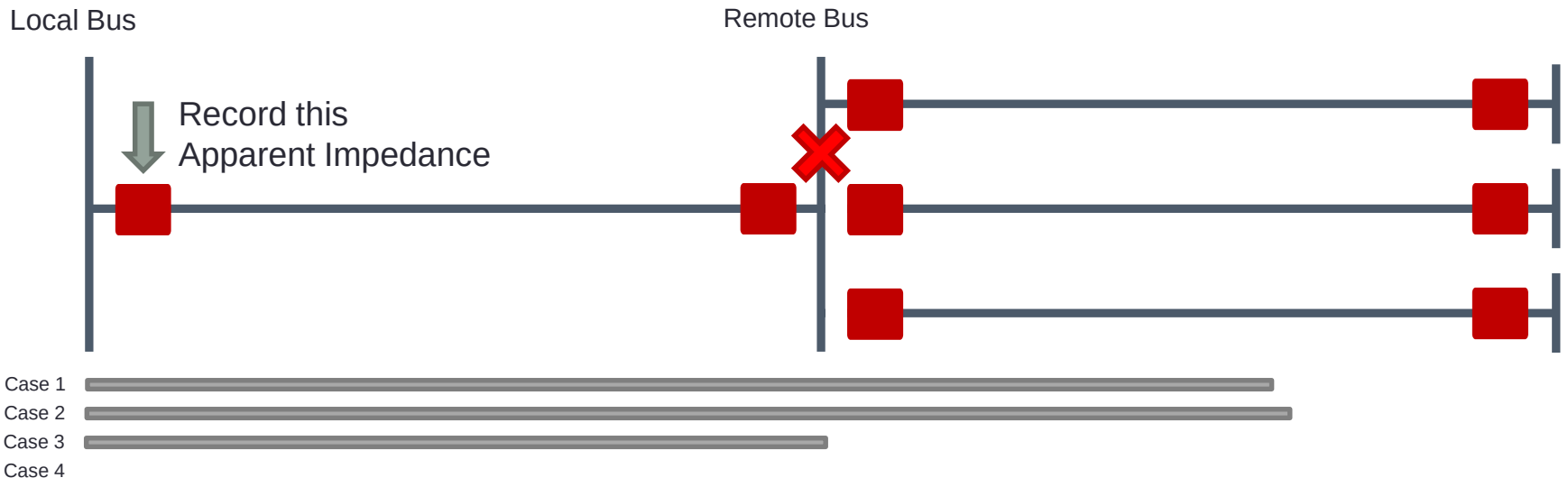


Actual Application

For Zone 2 however, an automation solution is necessary

4th Case:

- Take all remote lines out of service except one
- Do a Remote Bus Fault
- Record the Apparent Impedance at the primary line local relay
- Repeat for each remote line and find the minimum Apparent Impedance

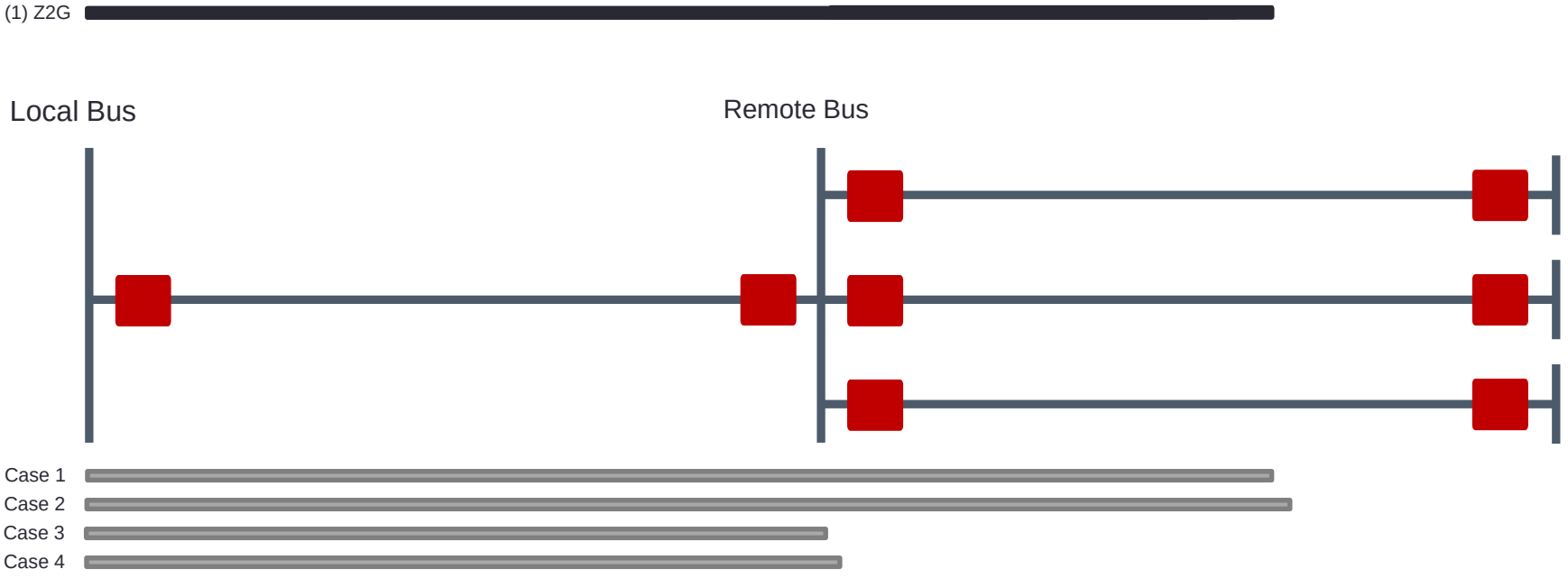


Actual Application

For Zone 2 however, an automation solution is necessary

The minimum of the following will be the Zone 2 Setting:

- (1) Z2G = 0.9 * (Case1 – Case3) + Case3
  - (Case1 – Case3)
  - 0.9 * (Case1 – Case3)
  - 0.9 * (Case1 – Case3) + Case 3

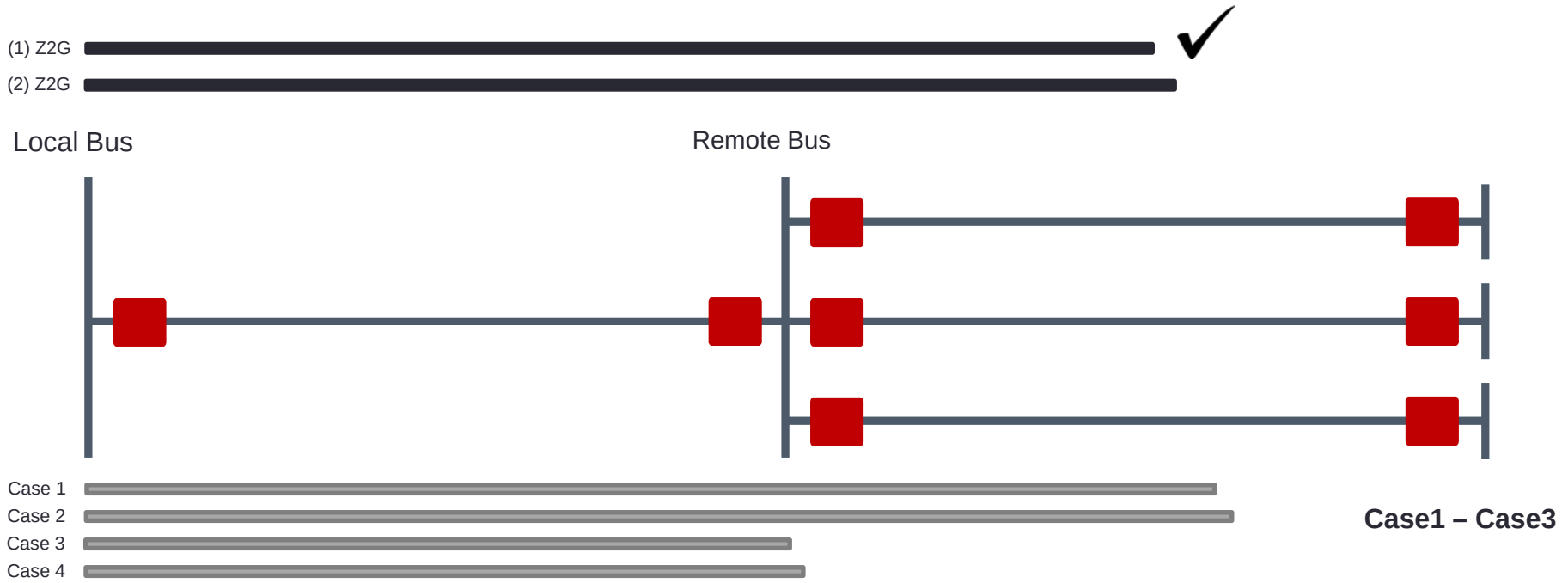


Actual Application

For Zone 2 however, an automation solution is necessary

The minimum of the following will be the Zone 2 Setting:

- (1) Z2G = 0.9 * (Case1 – Case3) + Case3
- (2) Z2G = 0.9 * (Case2 – Case4) + Case4



Z2P 1.235

Zone 2 Phase Distance Reach

$$A = 1.2 \cdot PL_{Z1Mag} \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 1.235$$

$$B = (PL_{Z1Mag} + 0.9 \cdot 0.85 \cdot SRL_{Z1Mag}) \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 1.232$$

$$C = (PL_{Z1Mag} \cdot BaseOhms + 0.9 \cdot SRLLocalZ1P_{relay}) \cdot \left(\frac{CTR}{PTR}\right) \quad 2.829$$

$$Z2P = \max(A, \min(B, C)) \quad 1.235$$

Z2MG 1.235

Zone 2 Ground Phase Distance Reach

$$A = 1.2 \cdot PL_{Z1Mag} \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 1.235$$

$$B = (PL_{Z1Mag} + 0.9 \cdot 0.85 \cdot SRL_{Z1Mag}) \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 1.232$$

$$C = (PL_{Z1Mag} \cdot BaseOhms + 0.9 \cdot SRLLocalZ1MG_{relay}) \cdot \left(\frac{CT}{PT}\right) \quad 2.829$$

$$Z2MG = \max(A, \min(B, C)) \quad 1.235$$

50PP1 6.25

Phase-Phase OC Fault Detector Zone 1

Z3P 5.291

Zone 3 Phase Distance Reach

$$A = (PLRemoteZ2P_{relay} - PL_{Z1Mag} \cdot BaseOhms) \cdot \left(\frac{CTR}{PTR}\right) \cdot 1 \quad 5.291$$

$$B = 1.2 \cdot LBL_{Z1Mag} \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 0.7519$$

$$Z3P = \max(A, B) \quad 5.291$$

Z1MG 0.8746

Zone 1 Ground Distance Reach

$$A = 0.85 \cdot \min(F4_{Zapparent}, F5_{Zapparent}, (PL_{Z1Mag} \cdot BaseOhms)) \cdot \quad 0.8746$$

$$B = \min(F4_{Zapparent}, F5_{Zapparent}) \cdot \left(\frac{CTR}{PTR}\right) - 0.1 \quad 1.9$$

$$Z1MG = \min(A, B) \quad 0.8746$$

Z3MG 5.291

Zone 3 Ground Distance Reach

$$A = (PLRemoteZ2P_{relay} - PL_{Z1Mag} \cdot BaseOhms) \cdot \left(\frac{CTR}{PTR}\right) \cdot 1 \quad 5.291$$

$$B = 1.2 \cdot LBL_{Z1Mag} \cdot BaseOhms \cdot \left(\frac{CTR}{PTR}\right) \quad 0.7519$$

- E can k

Case 4	xN	Remote Bus Fault
Case 5	xN	Sequenced (Multiple) Intermediate End-Open Fault
Case 6	xN	Sequenced (Multiple) Intermediate Fault
Case 7	x1	Remote Bus Fault
Case 8	xN	Remote Bus Fault

N = Number of Remote Lines

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Conclusion

- Existing methods for relay settings development can only employ relatively **basic calculation methods**. They are **error prone** and require an extensive **review process**.
- Automation can reduce errors and empower protection engineers to employ a more **precise settings philosophy**.
- Settings templates are a generalized philosophy description that can be used in any application.
- Approach can be extended to related fields (e.g., PRC-027 compliance, coordination).

Thank You

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Achieving Simplicity in System Protection

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