Exploring IEEE C37.120-2021 Guide for Protection System Redundancy for Power System Reliability

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Objectives

- Purpose of new standard document
- Redundancy definition and general considerations
- Protection component effect on redundancy
- Examples of redundancy application for power system equipment
- Summary

Why was this Guide developed

- NERC request for a standard document for protection system redundancy
- Assist protection engineers to select appropriate level of protection redundancy, based on industry best practices
  - Help users apply protection system redundancy
  - Provide information about factors to consider when designing redundant protection systems
  - To address different approaches in applying redundancy

Guide's Scope and Purpose

- **Scope**
  - This guide provides information about what factors to consider when determining the impact of protection system redundancy on power system reliability.

- **Purpose**
  - The purpose of this guide is to provide information on protection system redundancy considerations by illustrating the purpose of redundancy and how it may be implemented in the protection system design.

What is Protection System Redundancy?

- Protection system redundancy is the design of protection system to reduce the possibility that a single component failure would prevent the protection system from sensing and isolating a fault in its zone of protection.
  - Protection system includes relaying, auxiliary equipment, and tripping circuits

- The protection system is expected to work properly even when there are unwanted conditions within it, and redundancy addresses this.

Impact of Redundancy on Reliability

- Reliability is a combination of protection system dependability and security

- Redundancy increases dependability.
  - Increased dependability may reduce security
  - Reduced security may increase risk of unwanted operation.
  - Increase in dependability may not penalize security to the same degree

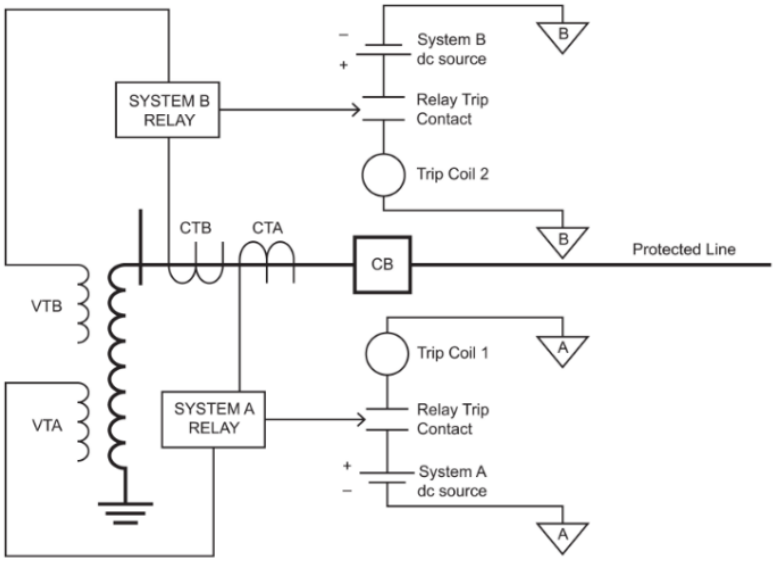
Considerations for Redundancy

- Simplicity is a very important component of good redundancy design
  - Complicated systems may be difficult to work with and could increase misoperation risk

- It’s important to understand what level of redundancy needs to be applied to a protection system
  - Guide helps to address this

Guide Redundancy Terminology

In the guide, System A and System B are used to designate, typically, two redundant relay systems as illustrated in this figure



Physical Redundancy

- Separate physical location of equipment helps reduce a possibility a single point of failure
- Equipment could be in the same substation but separated. Example: different paths for cables from switchyard to panel
- It is generally easier to accommodate physical separation in new designs than modifying a protection system in an existing substation.

Instrument Transformer Redundancy

- Dual secondary VT windings can be used for each protection system for redundancy
  - Two sets of VTs are redundant but might not be an option due to economic reasons and space constraints

- Separate CTs are used for each protection system for redundancy.

Battery/DC Source Redundancy

- Two battery systems consisting of a battery and a charger are redundant
  - Each battery system could be sized to handle the combined load of both systems A and B
  - Transfer schemes are implemented if one battery fails

Control/Breaker Trip Coil Circuit Redundancy

- If available, separate DC circuits could be used for each breaker trip coil to achieve redundancy

- If two independent relay systems are used, then each can trip an individual breaker trip coil
  - This could cause an undesirable scenario when one of the systems is in test, a fault occurs, and the other system fails

Relay System Redundancy

- There are several ways to help ensure redundancy in relay systems
  - They can be physically separated in the same panel or can be in separate panels
  - Using different manufacturers or different relay models from the same manufacturer for hardware redundancy
  - Relay vendors may use the same protective algorithms found in firmware code for the same protection function. To build redundancy, different protection functions could be used
  - Protection functions with different operating principles which complement each other may be used to achieve redundancy

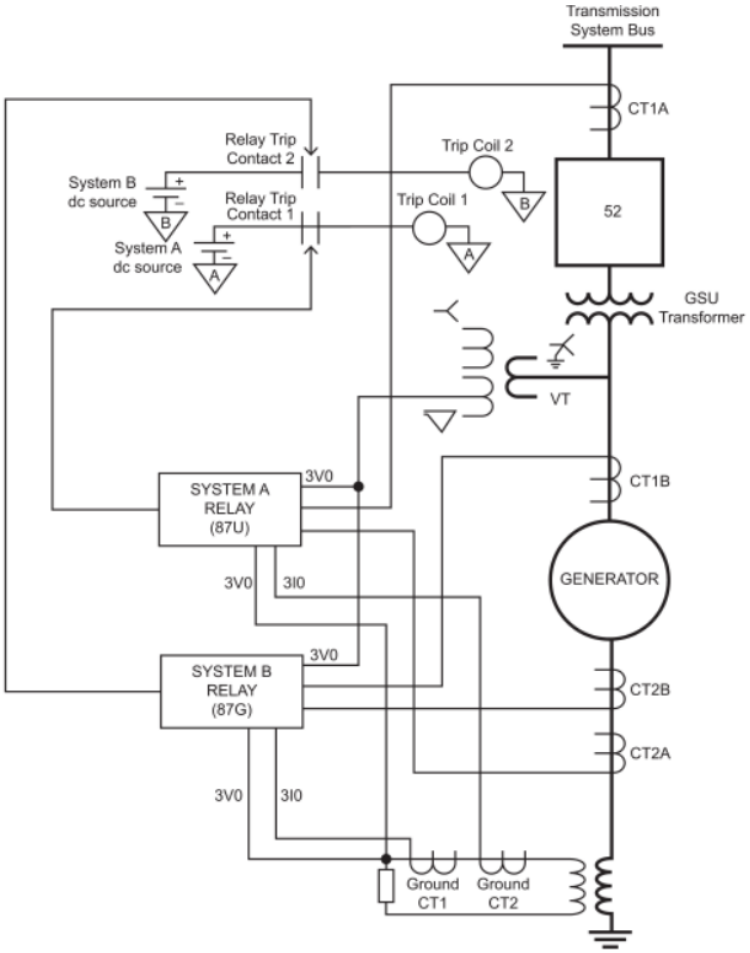
Communication Channel Redundancy

- Redundant communication channels may be used when the loss of a channel may cause undesirable operation
- Different forms of power line carrier channel can provide varying degrees of redundancy.
  - The highest level is for three-phase coupling
- The guide discusses various examples of communication channel redundancy for multiplexed digital networks

Local Area Network Redundancy

- Guide addresses redundancy in Ethernet LANs carrying protection functions
- Ethernet LANs can be configured to detect network failures and automatically switch over to another path
- SDNs simplify network management by placing management of individual devices to the common software control plane
- Redundancy of LAN for IEC-61850 and GOOSE messages is also discussed

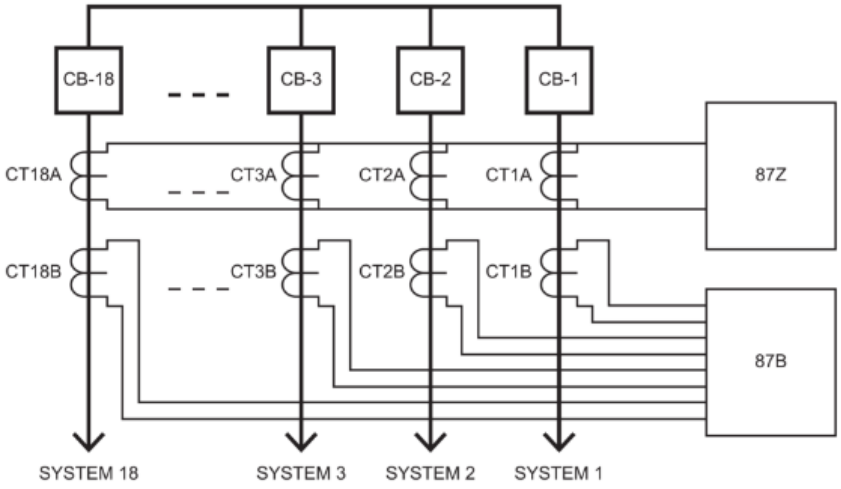
Generator Protection Redundancy



Bus Protection Redundancy

- Dual high impedance or percentage-restrained differential schemes or a combination of these schemes typically used for redundant protection of HV and EHV buses

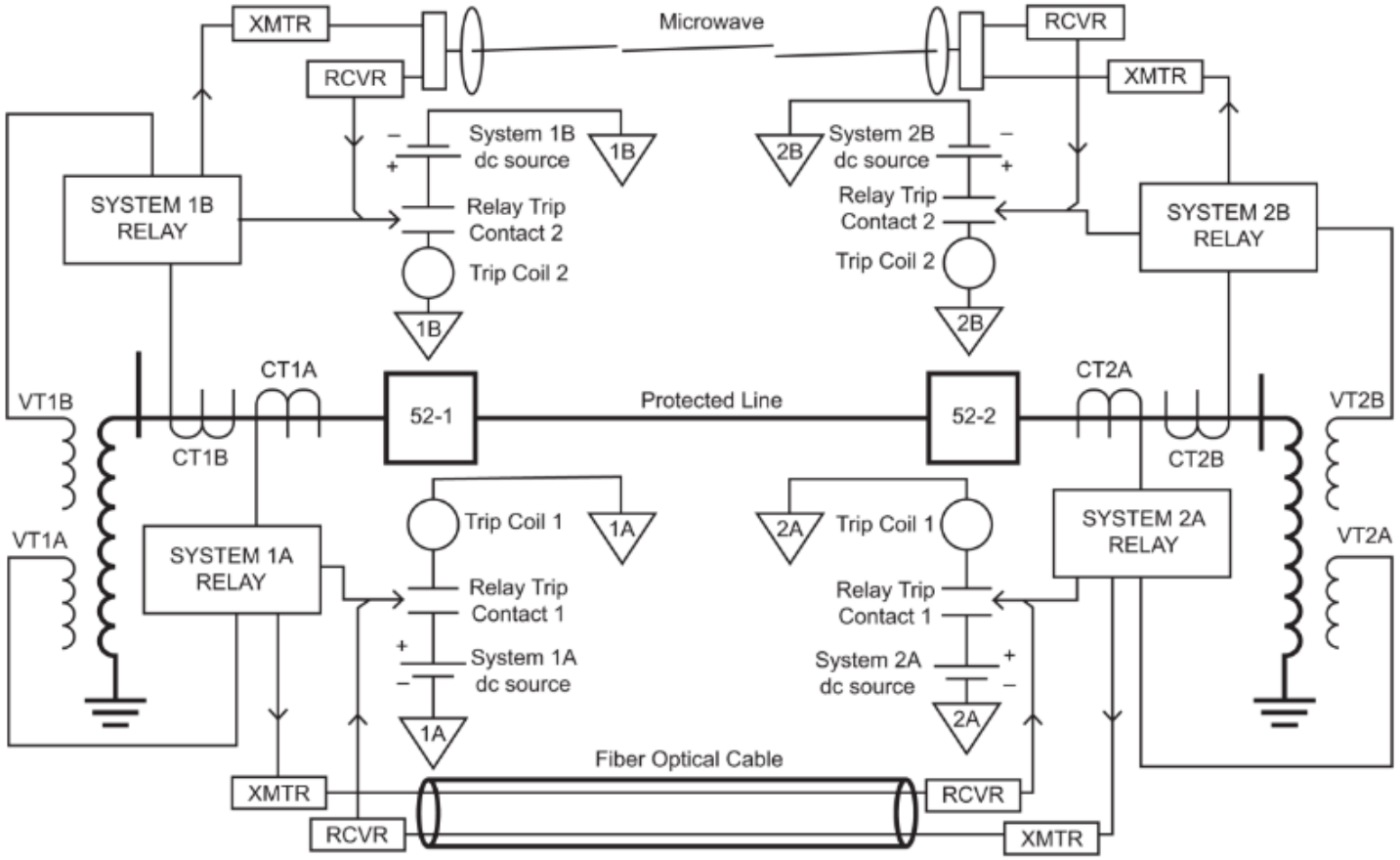
- For MV buses, transformer differential that includes a bus in its zone and a radial blocking zone-interlock protection with a definite time overcurrent is considered redundant



Line Protection Redundancy

- EHV transmission lines typically have redundant protection systems and communication channels since they are considered a critical path in the power system
- Different protection schemes can be used to avoid common mode failure
- System B can be of equal or lesser performance vs System A depending on needed redundancy level
  - For example, in EHV lines, it may be needed to have same level of performance on both relays

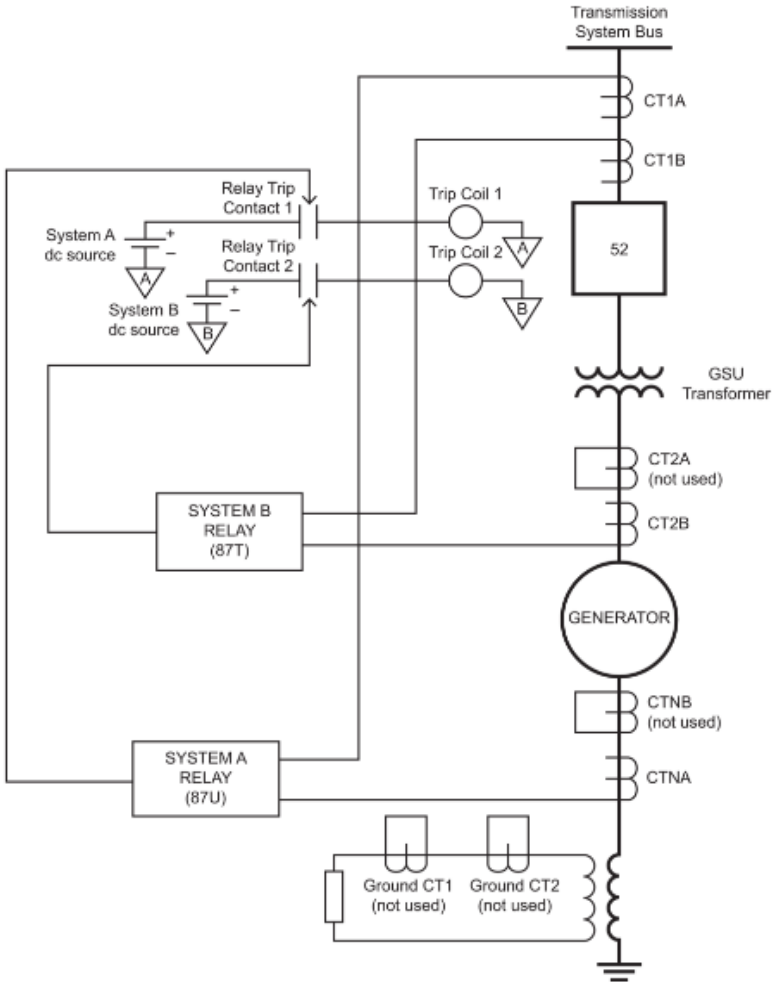
Line Protection Redundancy



Transformer Protection Redundancy

- Several protective functions in various combinations can be used to achieve redundancy in transformers
- The transformer MVA rating can be used to determine the redundancy for transformer protection
- Dedicated transformer differential and unit differential relays may be applied to achieve redundant protection for GSUs

Transformer Protection Redundancy



Shunt Reactor Protection Redundancy

- Protection is typically redundant for EHV shunt reactor units

- A way to achieve redundancy include using protective functions of relays protecting equipment adjacent to a reactor to provide its backup protection

Capacitor Bank Protection Redundancy

- To mitigate system stability issues during faults, transmission capacitor banks may have redundant overcurrent schemes using separate CTs
- Overvoltage and unbalance protection functions are usually not redundant since these conditions do not affect system stability
- Redundancy is typically not applied for distribution level capacitor banks

Breaker Failure Redundancy

- Breaker failure implemented to provide redundancy instead of using multiple circuit breakers
- Redundancy can be improved by maintaining independence between fault detection and breaker failure functions
- Multifunction relays which protect a power system element can be used for breaker failure protection
  - This scheme can add complexity but reduces cost and physical space required

Redundancy in Other Systems

- Redundancy in distribution systems is less common
  - Fewer customers affected if there is an individual protection component failure
  - Redundant protection may be used in some critical distribution loads
- SIPS have redundancy built into their design which may reduce security
- SCADA systems may not be redundant

Summary

- This guide outlines practical solutions for designing redundant protection systems
- Redundant protection systems enhance their response to clear faults and abnormal conditions
- The guide documents designing protection systems based on best industry practices and applications
  - Aimed at improving protection system reliability, i.e., dependability and security

Questions?