EE 5223 - Lecture 1 Mon Jan 11, 2021

Topics for Today:

- Introductions
- Startup
  - Book, Syllabus
  - Useful References
  - Course Expectations, Grading
    - Attend all lectures, actively participate.
    - Video starts rolling -- 2:00pm
    - Turn in work on time
    - Collect graded work, reconcile errors, stay on top of it!
    - Career Fair & Interview trips: not an excused absence
  - Labs - EE5224 - Begin in Week 3
  - Software - Aspen: 15-bus academic version
- Study Chapter 1, review Ch. 2, §3.1 thru §3.4
- How to read a one-line
- Instrument transformers, importance of polarity

- Intro to system protection. Always be aware of:
    - Reliability: dependability vs. security
    - Selectivity
    - Speed (i^2t heating ==> **“time = damage”**)
    - Simplicity, Economics
- Bus Configurations (see §10.1 thru §10.10)
- Basic Protection Strategies: IEEE C37.113
- Zones of protection

- Smart Grid Context will be provided as we progress (More on this later).

Grad School – What to Expect

- Smaller size classes. Everybody is a top student, high expectations. Top students to study with, collaborate with.
- Take an active role in your education. Anticipate what needs to be done. Ask questions during lecture.
- Open-ended problems and projects, larger scope, longer deadlines.
- Professor will create an environment (lecture, lab, research) for you to succeed in, you do the rest.
- Stress concept-based approaches (instead of procedural), abstract thinking, reward for developing creative innovative approaches.
- Communications – develop excellent speaking and writing skills.
- Research – scientific method, conceptually sound, make an advancement on existing state of the art.

Protection – From What?

- Lightning 5220
- Faults – S.C.s. ← 5223/4223
- Operational Errors (controls) – 5230
- Switching Surges (Overvoltages) – 5220
  R-L-C

– Of What?

- Lines, Cables
- Transformers – 30-50 yr life.
- Generators – 30-40 yrs
- Buses
- Motors
- Cap Banks, Reactor Banks
- FACTS devices. 10-20 yrs.

Key Goals of Protection ([redacted])
pp. 18-20

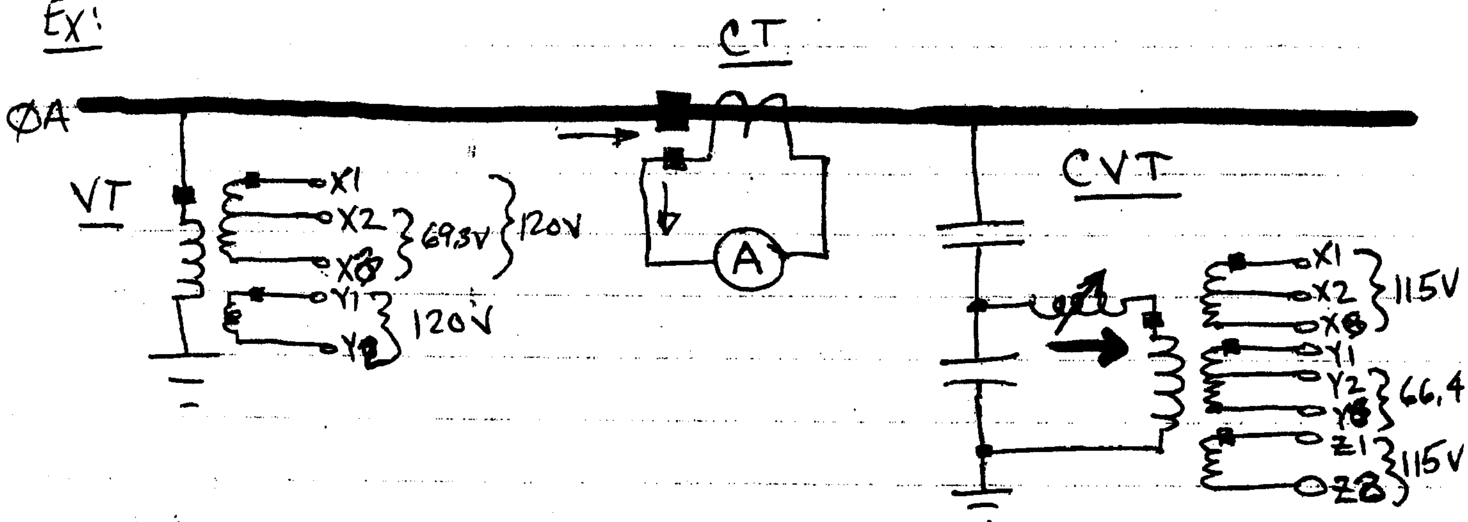
- Economics
- Reliable (always trip for problem)
- Fast ("time is damage")
- Selectivity (only trip what's needed) (Minimum)
- Simplicity
  - Fewer parts
  - Cheaper
  - Faster to troubleshoot/fix

Instrument transformers - used to "step down" primary voltages and currents to lower standard levels.

- Current: 0-5 A - CT

  Voltage: X1-X3: 0-120V } Voltage Tranformer (VT)
  X2-X3: 0-69.3V }
  X1-X3: 0-115V } CVT or CCVT
  X2-X3: 0-66.4V }

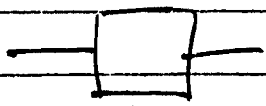
Ex:



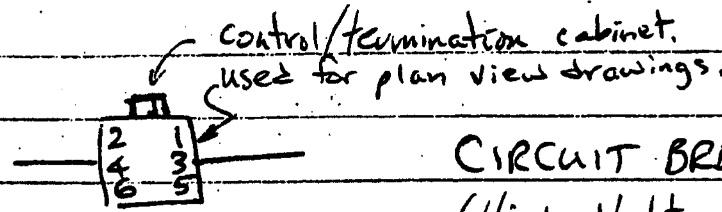
Note that "PT" designation is obsolete - new IEEE designation is "VT". Economics usually point to use of CVT or CCVT for voltages above 69-KV, VTs for lower voltages.

Note that linear couplers, which produce a secondary voltage proportional to the primary current, were in vogue for a while in the 50's & 60's but never caught on. Used mainly in bus differential schemes. Requires special relays (voltage instead of current input) - this additional cost hobbled it. (See p. 353, Blackburn)

One-line Symbols:

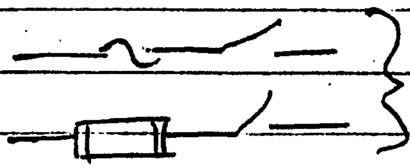


or

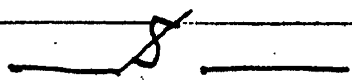


CIRCUIT BREAKER
(High Voltage)

Air-Break Circuit Breaker (Low Voltage)



or } Fused Disconnect Switch



Fused cutout

Disconnect Switch

Air-Break Switch w/arc restrictor

Circuit Switcher

~~Vacuum interrupter~~ trips first, then switch opens.
Can't interrupt high fault currents like CB, but cheaper.
Often used on HV side of transformer.
Can close & open on full load current also,
so provides function of load-break switch as well.

IEEE Std C37.113-1999

IEEE Guide for Protective Relay Applications to Transmission Lines

Sponsor

Power Systems Relaying Committee (PSRC)
of the
IEEE Power Engineering Society

Approved 16 September 1999

IEEE-SA Standards Board

Abstract: This newly developed guide compiles information on the application considerations of protective relays to ac transmission lines. The guide describes accepted transmission line protection schemes and the different electrical system parameters and situations that affect their application. Its purpose is to provide a reference for the selection of relay schemes and to assist less experienced protective relaying engineers in their application.
Keywords: protective relaying, relay application, relaying, transmission line protection

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-1831-1 SH94798
PDF: ISBN 0-7381-1832-x SS94798

Contents

IEEE Guide for Protective Relay Applications to Transmission Lines

1. Overview

This guide presents a review of the generally accepted transmission line protection schemes. Its purpose is to present the concepts of line protection and to describe the typical means of implementing such concepts. It is intended for engineers who have a working knowledge of power system protection or who have a need to understand the fundamentals of the various schemes. The fundamentals and definitions describing the relay schemes are written in a way intended to be understood by both relay and non-relay engineers. The circuits and operating characteristics of the various schemes are critically examined so the reader can understand and evaluate the advantages and disadvantages of the specific applications and evaluate alternative relays and relaying packages. This is an application guide and does not cover all of the protective requirements of all transmission line configurations in every situation. Additional reading material is suggested so the reader can evaluate the required protection for each application.

1.1 Scope

The study of transmission line protection offers an opportunity to examine many fundamental relaying considerations that apply, in one degree or another, to the protection of other types of power system equipment. Each electrical element, of course, will have protection problems unique to itself; however, the concepts associated with transmission line protection are fundamental to all other electrical devices and provide an excellent starting point to examine and appreciate the implementation of all power system protection. The basic relaying characteristics of reliability, selectivity, local and remote backup, zones of protection, coordination, and speed are present in almost all relaying situations. This guide specifically addresses these concepts for transmission line protection, but the ideas are universally applicable. Since transmission lines are also the links to adjacent lines or connected equipment, the protection provided for transmission lines must be compatible with the protection provided for all of these other elements. This requires coordination of settings, operating times, and characteristics. Individual relays, such as overcurrent, directional, and distance, as well as the total protection package, including the communication channels, are all examined in this guide, with appropriate discussion relating to their application and their particular advantages and disadvantages. Special topics, such as the effects of series capacitors or static volt ampere reactive (var) systems and consideration for tripping versus blocking during system power swing conditions, are also discussed.

In addition to the protection of the line itself, consideration is given to the various system configurations and bus arrangements, mutually coupled lines, reclosing, and the impact that system performance and parameters have on the selection of relays and relay schemes. Special protection systems, multiterminal lines, and single-phase tripping are among the topics covered.

2. References

This guide shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

IEEE Std 100 -1996, The IEEE Standard Dictionary of Electrical and Electronics Terms, Sixth Edition.[1]

IEEE Std C37.2-1996, IEEE Standard Electrical Power System Device Function Numbers and Contact Designations.

IEEE Std C37.90-1989 (Reaff 1994), IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus.

IEEE Std C37.90.1-1989 (Reaff 1994), IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.

IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear.

IEEE Std C37.109-1988 (Reaff 1999), IEEE Guide for the Protection of Shunt Reactors.

IEEE Std C37.110-1996, IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purposes.

3. Fundamentals

3.1 Terms and definitions

For the purpose of this guide, the following terms and definitions apply. IEEE Std 100-1996 should be referenced for terms and definitions not defined in this subclause.

3.1.1 Transmission line

Terms such as transmission, subtransmission, and distribution lines have different connotations among different companies. Such issues as what constitutes a line terminal may also vary among companies. Clauses of this guide will address the many line configurations and the effect these configurations may have on the protection of these lines.

For purposes of protection, a “line” is defined by the location of the circuit breakers (or other sectionalizing devices) that serve to isolate the line from other parts of the system. The line includes the sections of bus, overhead conductor, underground cable, and other electrical apparatus (including line traps, series capacitors, shunt reactors, and autotransformers) that fall between these circuit breakers. In Figure 1, segments 1 to 2 and 3 to 4 are defined as lines. It would normally be assumed that two or more stations are involved or the circuit breakers are too far apart to allow interconnection of control cables and station ground mats.

[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://www.standards.ieee.org/).

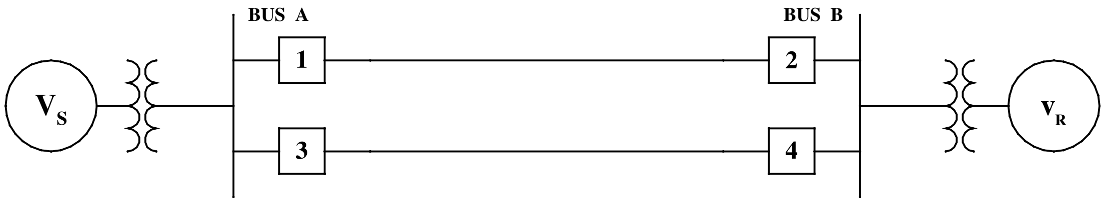


Figure 1—Definition of lines

3.1.2 Zone of protection

There are four basic types of protection zones, as shown in Figure 2. The four types are as follows:

a) Generator
b) Transformer
c) Bus
d) Lines

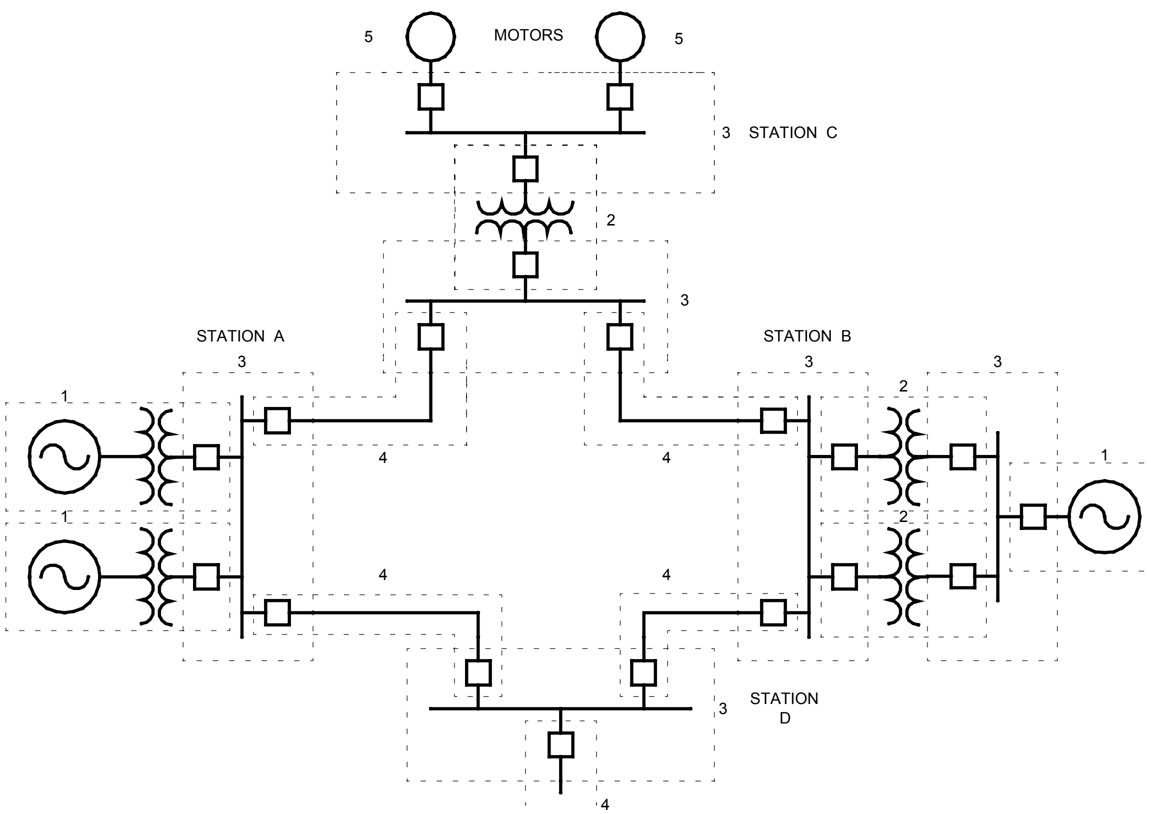


Figure 2—Typical system and its zones of protection

The boundaries of the zone of protection, as it applies to protective relays, are determined by the locations of the current transformers (CTs) that provide the representation of the line currents to the relays. Overlapping zones of protection is an established protection concept represented by Figure 3.

For pilot communication line protection schemes, the boundaries of the zone of protection are clearly defined. Many line protection practices, however, have unrestricted zones; the start of the zone is defined by the CT location, but the extent of the zone is determined by measurement of system quantities that may vary with generation and system configuration changes.

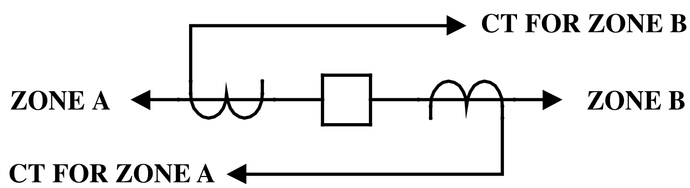


Figure 3—The principle of overlapping protection

3.1.3 Definitions

For the purposes of this standard, the following terms and definitions apply:

3.1.3.1 adaptive relay: A relay that can change its setting and/or relaying logic upon the occurrence of some external signal or event.

3.1.3.2 adaptive relaying: A protection philosophy that permits, and seeks to make adjustments automatically, in various protection functions to make them more attuned to prevailing power conditions.

3.1.3.3 apparent impedance: The impedance to a fault as seen by a distance relay is determined by the applied current and voltage. It may be different from the actual impedance because of current outfeed or current infeed at some point between the relay and the fault (see 5.5.1 and 5.5.2).

3.1.3.4 arc resistance: The impedance of an arc that is resistive by nature; it is a function of the current magnitude and arc length.

3.1.3.5 backup zone: The protected zone of a relay that is not the primary protection. It is usually time delayed (e.g., zones 2 and 3 of a distance relay). In addition, the backup zone will usually remove more of the system elements than required by the operation of the primary zone of protection.

3.1.3.6 blocking signal: A logic signal that is transmitted in a pilot scheme to prevent tripping.

3.1.3.7 breaker failure: The failure of a circuit breaker to operate or to interrupt a fault.

3.1.3.8 circuit switcher: A circuit interrupting device with a limited interrupting rating as compared with a circuit breaker. It is often integrated with a disconnecting switch. Its design usually precludes the integration of current transformers (CTs).

3.1.3.9 coordination of protection: The process of choosing settings or time delay characteristics of protective devices, such that operation of the devices will occur in a specified order to minimize customer service interruption and power system isolation due to a power system disturbance.