APPLICATION OF TIME DISTANCE RELAYS

TO TRANSMISSION LINE PROTECTION

M M MANN - C A DIFFENDAFFER - D G RUSSELL

Presented at the
Western Protective Relay Conference
Washington State University
held in
Sacramento, California
October 16, 17, 18, 1978

APPLICATION OF TIME-DISTANCE RELAYS TO TRANSMISSION LINE PROTECTION

ABSTRACT

This paper describes a new approach to transmission line relaying in which "fault magnitude variable tripping time" is used to achieve relay coordination without use of communication channels.

INTRODUCTION

A conventional distance relay provides the same tripping speed (fast) for all faults located within the relay reach setting. Application of this type relay requires a communication channel between line relay terminals to insure 100% of the line protection and still prevent tripping for line faults which are located outside of the protected line section.

The time-distance relay provides tripping time proportional to the distance from the relay to the fault and thus proportional to fault magnitude. In a time-distance relay application, the relay distance is set to overreach the protected line section by approximately 200%. This provides 100% coverage on the protected line and back up tripping for faults in the adjacent line section.

Communication channels are a source of problems in relaying and require considerable investment in initial and maintenance costs. In a search for a less complex and therefore less costly and more reliable relay scheme, it was decided to develop a scheme which does not require communication channels. A time distance scheme in which tripping time is proportional to fault distance appeared to fit this requirement and provide good protection. A tentative design for a time-distance relay was made and later it was discovered that Westinghouse was already making a time-distance relay, the SD-2.

Use of the time-distance concept is made possible by "fault magnitude variable tripping time" - the fact that as the fault is moved farther away from the relay bus, fault current at the relay bus is diminished and damage to apparatus, lines, and system stability is reduced thus allowing longer tripping times. Longer tripping times for far end faults allow the relays to be time coordinated with relays in adjacent line sections with no communication channel being required to prevent overreach tripping.

Comments on "Fault Magnitude Variable Tripping Time"

It is acknowledged that the factors influencing required fault clearing time are complex. Some considerations are line damage, transformer damage, insulator damage, and transient stability. Review of published computer studies on transient stability shows a wide range of calculated critical clearing times (1 cycle to 30 cycles). It is also apparent that critical clearing times from computer studies vary widely depending on the system and on which calculation method is used.

Idaho Power Company's approach is to determine required clearing times based on fault severity, which is related to both stability and damage. The guide used to determine maximum clearing time is based on an (IT) product of 1500 Ampere seconds for fault currents in the 1000 to 10,000 amp range and an (I^2T) product of 15 X 10^6 Ampere ^{2} seconds for fault currents above 10,000 amps.

Amps Fault Current	Max. Clearing Time in Cycles IT = 1500	$I^2T = 15X10^6$
1,000	90	---
2,000	45	---
4,000	23	---
6,000	15	---
8,000	11	---
10,000	9	9
12,000	---	6
14,000	---	4.6
16,000	---	3.5
18,000	---	2.8

Using the above guide, the designer determines maximum clearing times and designs to stay as far under these times as is economically reasonable. This utility has been using this guide for the past 8 years.

It has given good system protection with no equipment damage and has caused no problems with transient stability.

Application of the relays described herein as primary protection is limited to lines which can tolerate 12 cycles or more total clearing time for end zone (far end) faults. 12 cycles clearing time is not usually a limitation if an open minded approach is taken on the question: "How fast a clearing time is actually required?"

The Time-Distance Relay

The Westinghouse type SD-2 is a time-distance relay described by Westinghouse as suitable for phase to phase and 3 phase protection on 19 KV through 33 KV lines. The standard relay has tripping times ranging from 0.2 to 3.0 seconds.

With suitable modification to electronic circuits the tripping times of this relay are reduced to a range of 0.03 to 0.4 seconds. This faster tripping speed makes the relay suitable for protection on 138 KV and 230 KV lines.

Another modification of the SD-2 relay involves reconnecting internal current and voltage circuits so that an SD-2 can also be used for ground relaying.

A full complement of relays for one line terminal (using the SD-2) consists of;

1 - type SD-2 phase relay modified for fast trip

1 - type SD-2 relay modified for ground fault use and fast trip

1 - type KC-4 3 element induction cylinder instantaneous relay

1 - type 1RD-9 relay used for ground trip

Description of Individual Relay Functions

Type SD-2 Relay for Phase Fault Protection: This relay measures line to line voltage, and positive and negative sequence current (zero sequence current is excluded). It has been modified to give faster operating time by changing capacitor and resistor values in the electronics. Typical operating time is 0.04 seconds for a fault at 75% of relay reach. Time is adjustable over a wide range. Relay distance setting range is 0.8 to 25.6 ohms. The relay has a mho characteristic with maximum sensitivity at an angle of 60° current lagging voltage. The circle is slightly offset in the forward direction from the relay measuring point and cannot detect zero voltage faults. This relay is applied to give coverage between 20% and 200% of the protected line on phase to phase and 3 phase faults. Time setting is selected to give far end adjacent breaker clearing time for a close-in fault plus 5 cycles coordinating time.

Type SD-2G Relay for Ground Fault Protection: This relay has been modified to give faster tripping time in the same manner as the SD-2 for phase protection. It is modified to operate on line current which includes zero sequence current. Distance setting range is 1.6 to 51.2 ohms. Range of operating time and circle characteristics are the same as the SD-2 for phase protection. Because this relay is connected in phase currents, it measures I1 + I2 + I0 and will respond to 3 phase and phase to phase faults as well as phase to ground faults and thus provides back up for the 3 phase SD-2 relay. Relay reach setting and tripping time are selected the same as the relay for phase protection. Because of the time distance characteristic, relay reach accuracy is not critical. Reach must be set shorter than line load (usually not a serious limitation).

Type KC4 Relay for Phase and Ground First Zone Protection: a type KC4 3 element cylinder type instantaneous unit is connected with one element in each phase current and measures $I1 + I2 + I_0$. This relay has a trip time of 1.5 cycles and is set to cover zero to 30% of line length. All 3 separate elements operate independently of each other providing redundancy on 3 phase faults.

Type IRD Relay for Ground and Ground Back Up Protection: The IRD is used in a conventional manner to measure $3I_0$ current polarized with broken delta voltage, and or current. This relay is set to cover 50% of the line on its instantaneous unit and provide time coordinated overreaching back up on the time overcurrent unit.

All internal line faults are covered by one primary and at least one backup function.

Fault Testing

This scheme has been tested on the Utah Power and Light "Power System Simulator" at Salt Lake City. Also Idaho Power Company has performed staged fault tests on the scheme (2 terminals have been in service for approximately one year). Advantages of the scheme are; much lower cost, no channel reliability problems, it can be designed, set, and tested single ended.

Summary

Often fast clearing times are requested due to lack of knowledge about what is actually required on a specific application. Broad generalization about needing to clear all faults as fast as possible can lead to costly, complex and less reliable relay schemes. Application of the time-distance scheme to transmission line protection is made possible by using realistic longer tripping times for clearing remote terminals when fault currents are low. This allows coordination time for end zone faults and no communication channel is required. The advantages of increased reliability, reduced cost, reduced maintenance, and reduced complexity are considerable.

APPENDIX 1

Cost Comparison of SD2 Scheme VS Conventional Relays

SD2 SCHEME

1 - Modified SD2 time distance relay for phase protection

1 - Modified SD2 time distance relay for ground protection

1 - KC4 for first zone instantaneous protection

1 - IRD directional overcurrent ground relay for ground protection

Total cost of relays - $5,800

Conventional Scheme

1 - Impedance relay for zone 1 protection

1 - Impedance relay for zone 2 protection

1 - Impedance relay for zone 3 protection

1 - Directional overcurrent ground relay

1 - Directional overcurrent ground relay for ground backup

1 - Time delay relay for backup timer

1 - Carrier auxiliary relay

1 - Carrier set

1 - Test switch

1 - Milliammeter

1 - Carrier coupler

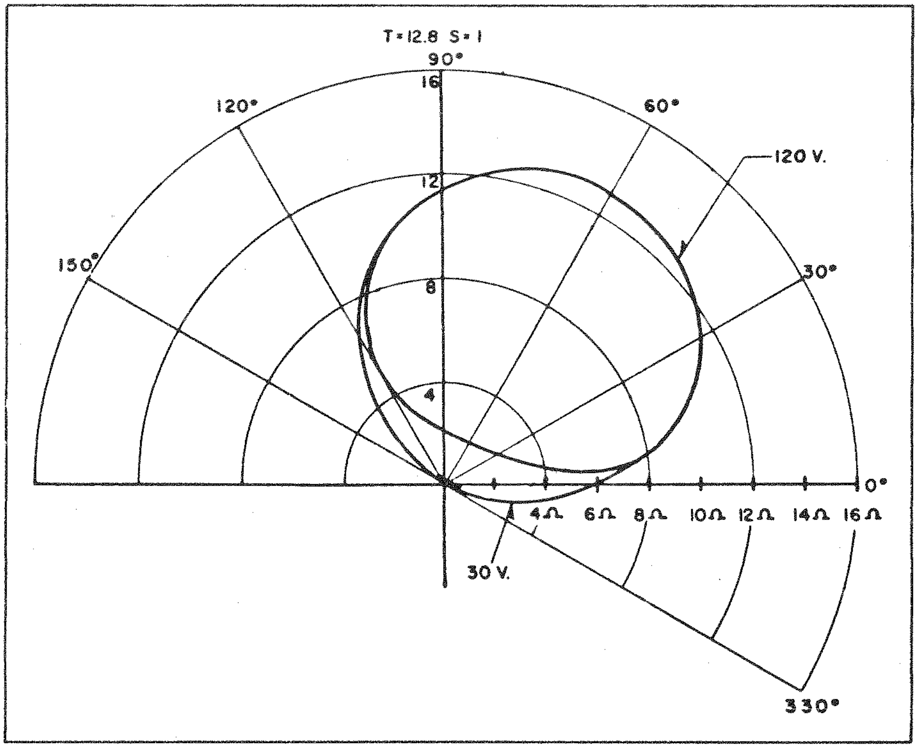
1 - Carrier wave trap

1 - Carrier line tuner

Total cost of equipment - $13,800

The reduction of equipment cost is $13,800 - $5,800 = $8,000 per line terminal. This is a 58% reduction. Also, the SD2 scheme results in a reduction of 50% in panel space, 40% in wiring time, and 50% in design time. Installation testing is reduced by 60%. Estimated total reduction is $9,420 per line terminal, or 68%

FIGURE 1



Impedance Circles for the SD-2 Relay

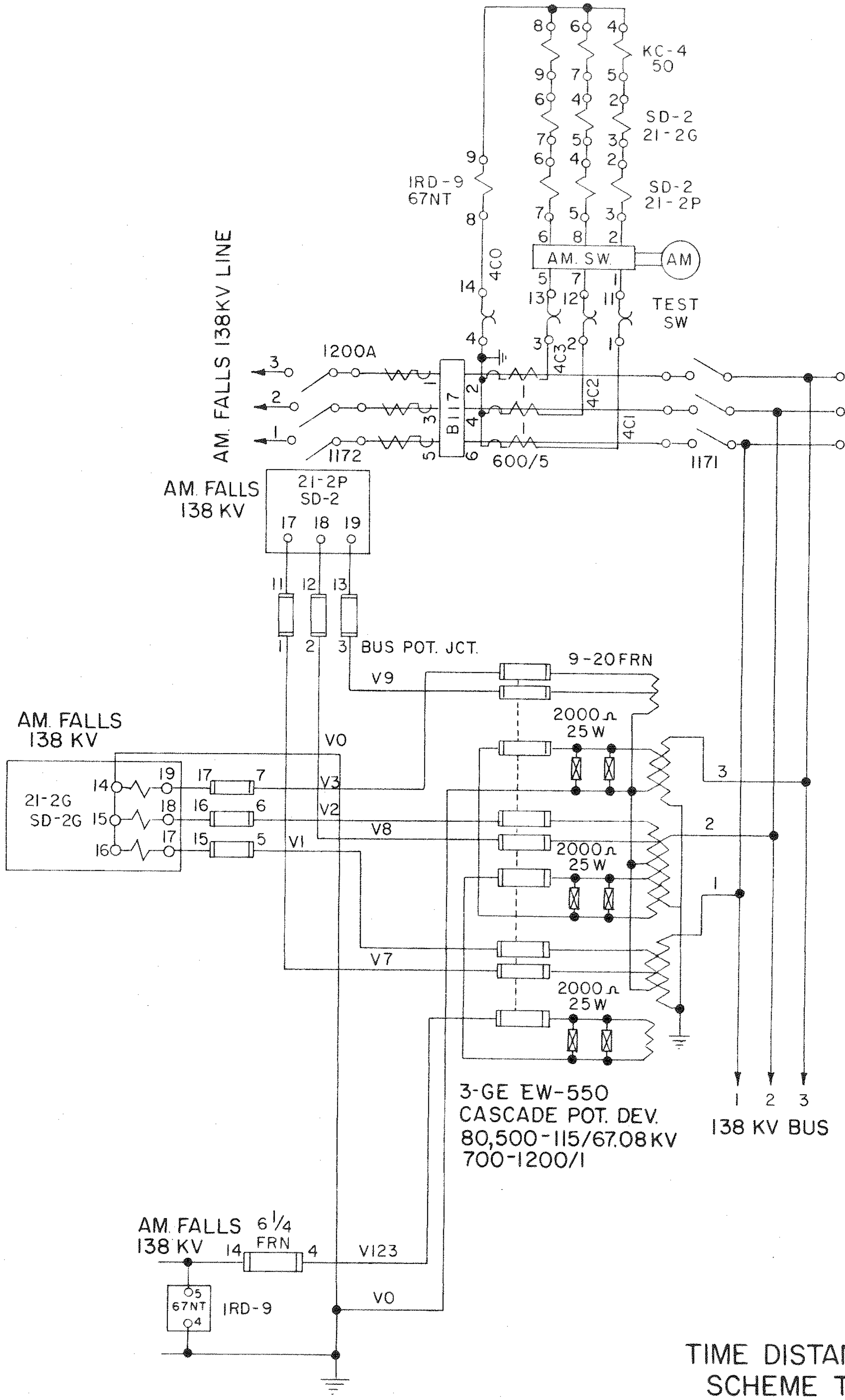
FIGURE 2

Typical Relay Responses and Operating Times

Relay Output Time in Cycles (60 HZ Base)

Fault Location	Relay Bus	25% of Line	50% of Line	Remote End	150% of Line
Fault Type 3Ø	1.5 (KC4)	1.5 (KC4) 1.5 (SD2-Ø) 1.6 (SD2-G)	3.5 (SD2-G) 4.0 (SD2-Ø)	10.5 (SD2-G) 11.0 (SD2-Ø)	18 (SD2-G) 19 (SD2-Ø)
Ø-G	2.0 (IRD-IT) 3.0 (KC4) 4.0 (SD2-G)	4.0 (SD2-G) 2.0 (IRD-IT) 3.0 (KC4)	8.0 (SD2-G) 8.1 (IRD-IT)	11.0 (SD2-G) 42.0 (IRD-T)	36 (SD2-G)
Ø-Ø	2.0 (KC4) 4.0 (SD2-G)	2.0 (KC4) 3.0 (SD2-Ø) 3.0 (SD2-G)	4.5 (SD2-Ø) 5.5 (SD2-G)	10.5 (SD2-Ø) 11.0 (SD2-G)	21 (SD2-Ø) 22 (SD2-G)

FIGURE 3



TIME DISTANCE RELAY
SCHEME TYPE SD2
AC SCHEMATIC