SUMMARY OF RELAY TRIP CIRCUIT DESIGN

A Summary of an IEEE Special Publication
by the
PSRC Relay Trip Circuit Design WG

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D. C. Dawson, Chair
J. P. Gosalia, V. Chair

D. C. Blackburn, Jr.
S. P. Conrad
C. W. Fromén
S. E. Grier

R. W. Haas
R. E. Hart
I. O. Hasenwinkle
J. D. Huddleston III
M. J. McDonald

G. P. Moskos
R. P. Oñate
J. E. Stephens
D. A. Tziouvaras

Abstract: The Relay Trip Circuit Design Working Group of the IEEE Power System Relaying Committee has prepared a Special Publication to document and share information about the practices of electric utilities in design of protective relay tripping circuits and associated apparatus. The Special Publication is available on the PSRC web site at the URL: http://www.ewh.ieee.org/soc/pes/psrc/k/Kreports.html. This paper is a summary of the content of the Special Publication.

Keywords: Circuit breaker, electric utilities, power industry, power system protection, power system relaying, protective relaying, switchgear

I. INTRODUCTION

This IEEE Special Publication has been prepared by the Relay Trip Circuit Design Working Group of the Power System Relaying Committee. Its purpose is to document and share information about the practices of electric utilities in the design of protective relay tripping circuits and associated control and protective functions. This information has not been widely disseminated before this publication. This document it not a recommended practice or design guide. Trip circuit design has evolved over many years in different utilities and practices vary widely. Designs by individual utilities are influenced by their individual operating practices and experience.

The practices described in this Special Publication generally pertain to component relays where the functions of fault detection, timing, communication, and tripping are performed by separate units connected in a customized configuration by the individual utility. The increasing acceptance of digital integrated relay systems will alleviate many of the issues discussed in this document. However, since these new digital relays require auxiliary power, contain surge protection, and must be integrated into existing systems, the information presented in this document should be of continuing interest.

II. SUBSTATION DC SYSTEMS

Relay Trip Circuit Design begins with an extensive review of the various approaches used in the design of dc distribution systems. The purpose of the dc system for substations and switchyards is to provide a reliable source of auxiliary power for the station's control and protection functions. The dc system consists of the station storage battery(s), associated charger(s), and the distribution system necessary to supply the control power for the power circuit breakers and power supplies of electronic apparatus. The design objectives are:

- Provide a level of reliability consistent with the reliability of the rest of the protective system.
- Arrange the feeders in a logical pattern so that the effects of a dc feeder outage will be readily apparent to operating and maintenance personnel.
- Provide a sufficient number of feeders to permit maintenance outages without jeopardizing system protection.
- Keep currents and voltage drops to acceptable values.
- Accomplish the above objectives at minimum cost.

Various dc distribution systems are discussed in the document. Fig. 1 shows a common distribution arrangement: the feeder-per-breaker scheme where a separate dc feeder, originating at the dc panel, is used for each switchyard power circuit breaker or control circuit. This feeder supplies tripping and closing power for the circuit breakers, protective relay power, and any auxiliary power for other devices or tripping relays.

Abstract ID Number: 2000SM-303

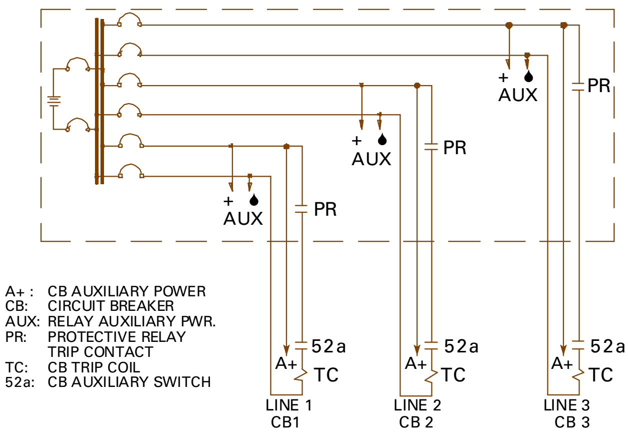

Fig. 1. Feeder-per-Breaker dc Arrangement

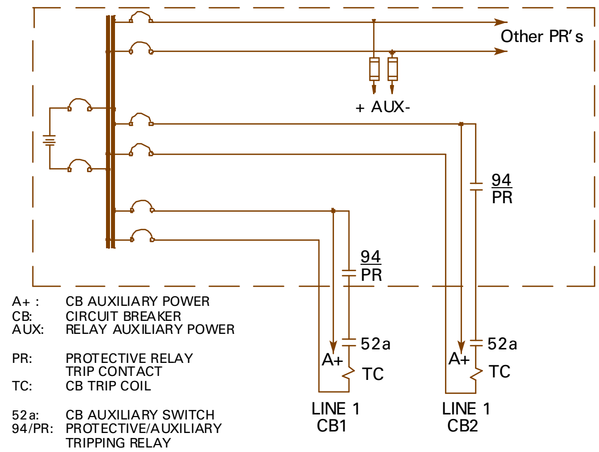

Fig. 2. Tapped Feeder dc Arrangement

A second approach is the tapped-feeder or tapped-bus scheme shown on Fig. 2. In this case, the dc panel breaker supplies a number of different control circuits through a branch tap on the feeder or bus conductors. The tap point may be either fused or not fused. Several arrangements of this scheme are discussed together with considerations for arranging the feeders. The advantages and disadvantages of the feeder-per-breaker, fused tap-feeder, and unfused tap-feeder distribution systems are discussed in detail in the Special Publication.

There are several methods of routing trip circuits which may appear to be equivalent but have significant differences in terms of voltage drop, electromagnetic interference, and cost. These are described as "radial system" where the positive and negative supply conductors are routed together, and the "looped system", where the positive and negative circuits follow different paths. Aspects of the radial system are discussed along with its advantages relative to the looped system. A radial system is preferred to loop systems in order to minimize inductive surges.

The ratings of fuses or circuit breakers should be applicable to dc systems. Fault currents should be calculated to verify interrupting ratings and to check coordination of the protective devices. In coordinating protective devices, the manufacturer's characteristic curves should usually be used to verify selectivity.

III. TRIP CIRCUITS

Two approaches are used in the design of trip circuits: direct trip, where each circuit breaker is directly tripped by the protective relays, and indirect trip, where tripping is accomplished through diodes or auxiliary relays. The former is generally used to trip a single circuit breaker and the latter is required where more than one breaker is opened.

One aspect of direct tripping that should be considered is the selection of targets and problems associated with parallel target and seal-in paths for electromechanical relays. Trip coil current will divide among several targets when more than one relay trips a circuit breaker. The impedance in each path should be checked to ensure that the targets will operate. It may be necessary to add resistance in some circuits. In addition to tripping breakers, protective relays may also operate other auxiliary relays, timers, and key communication transmitters. Target and seal-in (TSI) coils should be selected so that the current drawn by these devices is not sufficient to operate the TSI. The dropout of a TSI coil is typically 30-50% of the coil rating and the coil should also be selected so that the TSI does not remain held up by these auxiliary devices after it has operated.

Dual trip coils in circuit breakers are frequently used to provide a redundant tripping path and have become standard practice on EHV systems. When two trip coils are used, the control circuit for each should be completely isolated from the other. It is a popular practice to operate one trip coil from the primary relay system and the second from the backup system. This is usually satisfactory; however, unnecessary breaker failure tripping can occur when the primary relaying is high-speed and the secondary relaying operates after a time-delay. This can happen should the main trip coil fail to

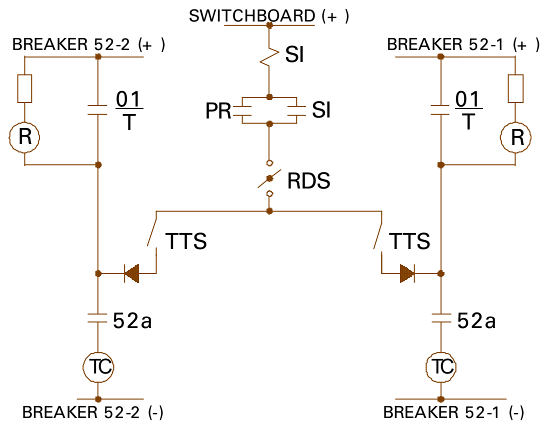

Fig. 3. Tripping Two Breakers with Diodes

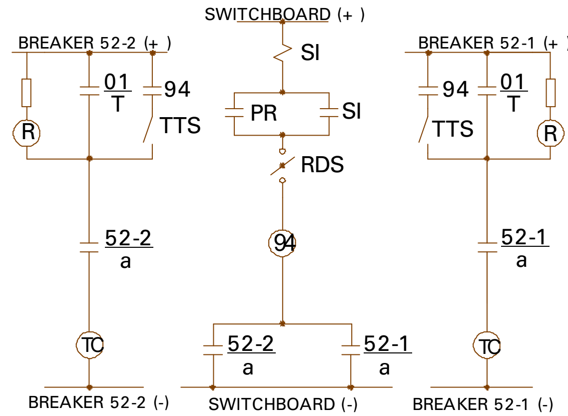

Fig. 4. Tripping Two Breakers with an Auxiliary Relay

function during a fault and the breaker failure operating time is faster than the backup relay time which is frequently the case for faults near the remote terminal of the line. This problem can be overcome by either retripping or cross-tripping. Both of these techniques are presented in the Special Publication.
Tripping multiple circuit breakers is required when the bus is configured in a 1-1/2 breaker, ring, or double bus, double breaker arrangement. This can be accomplished with either diodes or auxiliary relays as shown on Figs. 3 and 4.

The Special Publication discusses the relative advantages and disadvantages of diodes and auxiliary relays in detail and mentions special application considerations which are important for diodes.

The rated voltage of auxiliary tripping relays can range between 10 to 25% of the control voltage in order to provide high speed operation. This will also provide sufficient current to operate the relay targets, but some means is required to disconnect the coil or reduce the voltage after the relay is picked up to avoid damage to relay. High operating speeds can also be obtained by low inertia auxiliary relays rated at the control voltage. However, these relays require parallel loading resistors to ensure operation of the target and seal-in relays.

In either case, auxiliary relays require provisions to return the circuit to normal after the breaker has tripped. There are several methods of doing this which are illustrated in detail in the Special Publication.

IV. BREAKER FAILURE RELAYING INITIATION

When local breaker failure relaying is used, it should be initiated by all protective relays which normally trip the circuit breaker including direct or permissive transfer trip from remote terminals. Some utilities do not, however, initiate breaker failure relaying from other breaker failure circuits. Breaker failure relaying may be initiated by auxiliary tripping relays, separate breaker failure relaying initiation (BFI) relays, or separate BFI outputs from the main relay. BFI auxiliary relays should have fast pick-up and drop-out and low operating current.

Breaker failure relaying should be designed so that a failure in the primary or backup relay circuits does not affect the integrity of the remaining circuit or the operation of the breaker failure scheme. Accordingly, there should be a maximum practical degree of separation of these circuits. The Special Publication discusses several techniques which can be used to maintain this separation.

Certain types of relay systems must be checked to ensure that breaker failure relaying initiation is properly maintained. The publication provides information about five such problem areas which warrant special attention. Potential problems with unwanted operation of seal-in circuits by BFI relays are also addressed.

In general, breaker 52a auxiliary switches should not be used to initiate breaker failure relays except as a supplement to the current fault detector when the current fault detector lacks the sensitivity to operate for all faults in the zone of protection. This can occur, for example, with transformers.

V. TRANSFER TRIPPING

Transfer trip can include direct transfer trip, used for remote tripping on transformers, reactors, or breaker failure, or permissive transfer trip, used for pilot protection of transmission lines. Each has specific requirements, the details of which are described in the document.

The primary concern for transfer tripping circuits is security against false trips. The following approaches are suggested in the publication to enhance security against false trips:

- High level of threshold voltage to initiate keying (70% or more)
- Avoid excessive lengths in the cables on keying circuits or use shielded cables.
- Keep the input impedance to the keying circuit low.
- Do not use capacitors in the keying circuit.
- On frequency shift channels, use the guard output of the receiver with logic appropriate to the relaying function (This feature is not required for digital channels which have built-in monitoring and alarm circuits).

Normally, functional test facilities should be provided at both ends. This usually consists of a control switch with at least three positions for OFF, ON, and TEST.

VI. POLE DISAGREEMENT RELAYING AND INDEPENDENT POLE TRIPPING

The three poles of most modern circuit breakers used on EHV systems are capable of independent operation. With independent pole operation, a pole may fail to operate, however, the remaining poles will open during a fault. This has an advantage of potentially degrading a multi-phase fault to a single-line-to-ground fault which is less severe from the standpoint of system stability. However, it is still necessary to open the backup breakers via breaker failure relaying.

The Special Publication describes pole disagreement relaying, using a series/parallel combination of breaker 52a and 52b contacts. Independent pole operation also provides opportunities for single-pole tripping and reclosing, however, this aspect is not discussed.

VII. TRIP CIRCUIT MONITORING AND SUPERVISION

Trip circuit monitoring is frequently accomplished by a red lamp in series with the breaker 52a contacts and the trip coil along with a green light in series with a 52b contact. Other schemes are used by utilities to provide local and SCADA alarm indication of the dc supply. Several schemes for remote indication are discussed in the document.

VIII. RECLOSE INITIATION AND CANCELLATION

High voltage transmission lines frequently use automatic reclosing schemes which allow reclosing only on the operation of certain relays and block reclosing for the operation of other relays. The needs of these reclosing schemes can influence the design of trip circuits.

Reclose initiation permits the operation of the reclosing relay only when the breaker has been tripped for faults where reclosing is desired. This is accomplished by segregating the trip signals from relays using diodes or auxiliary relays. The Special Publication describes in detail how Reclosing Initiation signals can be derived and used to provide the desired performance.

Since it is not possible to ensure that reclose initiation will always guarantee that unwanted automatic reclosing operations will not occur, reclose blocking is also used. Normally, blocking is required for both automatic and manual reclosing of bus and transformer faults or breaker failure. Since this protection will ordinarily operate lock-out auxiliary tripping relays, it is usual practice to simply wire normally closed contacts of the lock-out relay in the close circuit. If precautions are not taken, certain reclosing relays will operate as soon as the lockout relay is reset, resulting in an unwanted breaker closing operation.

IX. TRIP CIRCUIT APPARATUS

In addition to discussing the design of relay trip circuits, this Special Publication includes a detailed description of devices normally used in these circuits as well as their characteristics and the difficulties sometimes encountered with these devices. Included in these discussions are:

- Auxiliary relays
- Static relays
- Lock-out relays
- Target devices
- Breaker trip coils
- Surge protective devices
- Test switches

XI. REFERENCES, BIBLIOGRAPHY, AND APPENDIX

The final sections of the Special Publication provide references and a bibliography of papers dealing with trip circuit and dc system design issues. An appendix provides test results on the minimum time/current values needed to successfully operate typical electromechanical target relays.

XI. CONCLUSION

Relay Trip Circuit Design is a Special Publication that should find wide practical application in the utility industry. It summarizes in one document many of the items that require consideration in the design of circuits for the operation and control of circuit breakers. This information has not been widely disseminated before and the Working Group hopes that its publication may help to encourage uniformity as well as help others avoid the snares and pitfalls which have been found through hard experience.

Obtaining a Copy

A zip file containing the Relay Trip Circuit Design Special Publication is available on the Internet for downloading at: http://www.ewh.ieee.org/soc/pes/psrc/k/Ktrpsrktdezin.html. The document is in Microsoft® Word for Windows® version 7.0 format. The PSRC World Wide Web home page is at: http://www.pes-psrc.org.