Relaying and System Protection for Electric Utilities - Volume I: Principles of Protective Relaying

An Online Continuing Education Course for Engineers

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Relaying and System Protection for Electric Utilities Volume I: Principles of Protective Relaying

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Preface

This course is one of a series of five courses on the design of relaying and system protection programs for electric utilities. These courses describe the fundamental concepts of electric system protection and provide detailed examples of the application of relaying. In most cases, the material is based on electro-mechanical relays to give the reader a strong understanding of current relaying practices. However, today, practically all new relay schemes use microprocessor-based relays, and the relay operating procedures are based on the electro-mechanical relay schemes that served the utility industry for almost 100 years. Where it adds clarity, microprocessor-based relay schemes are covered.

This series is divided into five separate courses. Each course essentially stands on its own, and the courses do not necessarily need to be taken in the order listed. However, for a thorough understanding, it makes sense to take the courses are presented. These are the course titles:

Volume I – Relaying Principles. This course discusses the principles of electric system protection and the nomenclature and taxonomy of relaying. Different relaying types and concepts are broadly discussed. This course provides the fundamentals and is important for understanding the concepts presented in other volumes.

Volume II – Instrument Transformers. The course explains the types of instrument transformers used in relaying protection schemes, their characteristics, and their limitations. Virtually all relay schemes required instrument transformers to receive useful information on system conditions.

Volume III – Line Protection. This course describes the relaying schemes and processes used to protect transmission lines. Distribution line protection is only briefly covered. Line protection includes the application of overcurrent relays, directional overcurrent relays, distance relays, and pilot relay schemes.

Volume IV – Substation Protection. This course explains methods to protect substation buswork as well as substation transformers. The primary protective scheme covered in this course is differential relay schemes.

Volume V- Generator and Motor Protection. This course describes the methods of protecting utility generators and motors. Differential relay schemes and thermal relay devices are covered.

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Introduction

Protective relays are used to detect defective lines or apparatus and to initiate the operation of circuit-interrupting devices to isolate the defective equipment. Relays are also used to detect abnormal or undesirable operating conditions other than those caused by defective equipment and either operate an alarm or initiate the operation of circuit-interrupting devices. The goal of protective relaying is to minimize damage to the electric system while maintaining service continuity to the unaffected portions of the system.

An effective and efficient protective system should have the following six characteristics:

1. Dependability
2. Selectivity
3. Security
4. Speed
5. Simplicity
6. Economy

Dependability is the certainty of correct operation in response to system disturbances. Dependability includes the reliable operation of the relay system operating. *Selectivity* is the operation of the relay system to isolate the minimum amount of the system necessary to provide continuity of service. *Security* is the ability to avoid misoperations; every relay system must be designed to either operate or not operate selectively with other systems. *Speed* means clearing faults in the shortest possible time with all due regard to dependability and security. *Simplicity* states that a relaying system should be no more complex than is required for any given application. A poor *economy* refers to the addition of more equipment into a scheme than is necessary for good coverage, which increases costs and increases the possibility of equipment failure and misoperation.

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Protective relaying is sometimes referred to as an "art." This is because the six items described above must be balanced to meet the complex demands of the system. The art of protective relaying includes consideration for:

- Economics - initial, operating, and maintenance costs
- Operating Practice - conforming to existing standards and practices, permitting efficient system operation, and flexible for foreseeable future changes
- Previous Experience - protection frequently emphasized for issues previously experienced and de-emphasized for issues not encountered
- Available Indications of Faults or Issues - fault magnitudes and location and connection of instrument transformer devices

The function of protective relaying is to cause the prompt removal from service of any element of a power system when it suffers a short circuit or when it starts to operate in any abnormal manner that might cause damage or otherwise interfere with the effective operation of the rest of the system. The relaying equipment is aided in this task by circuit breakers that can disconnect the faulty element when they are called upon to do so by the relaying equipment.

Circuit breakers are generally located so that each generator, transformer, bus, transmission line, etc., can be completely disconnected from the rest of the system. These circuit breakers must have sufficient capacity so that they can carry momentarily the maximum short-circuit current that can flow through them, and then interrupt this current; they must also withstand closing in on such a short circuit and then interrupting it according to certain prescribed standards.

Although the principal function of protective relaying is to mitigate the effects of short circuits, other abnormal operating conditions arise that also require the services of protective relaying. This is particularly true of generators and motors.

A secondary function of protective relaying is to provide an indication of the location and type of failure. Such data not only assists in expediting repair but also, by comparison with human observation and automatic oscillograph records, provides means for analyzing the effectiveness of the fault-prevention and mitigation features, including the protective relaying itself. Some of the issues that must be addressed include,

- Short circuits
- Overcurrents
- Temperature constraints
- Frequency deviations
- Over-speed conditions

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These issues are briefly discussed below.

A *short circuit* is an abnormal connection of relatively low resistance between two or more points of differing potential in a circuit. If one of these points is at ground potential, it is referred to as a *ground fault*. If ground potential is not involved, it is referred to as a *phase fault*. Phase faults cause excessive currents and low voltages. Ground faults may or may not cause excessive currents or abnormal voltages, depending on whether the system is normally ungrounded, high- or low-resistance grounded or effectively grounded.

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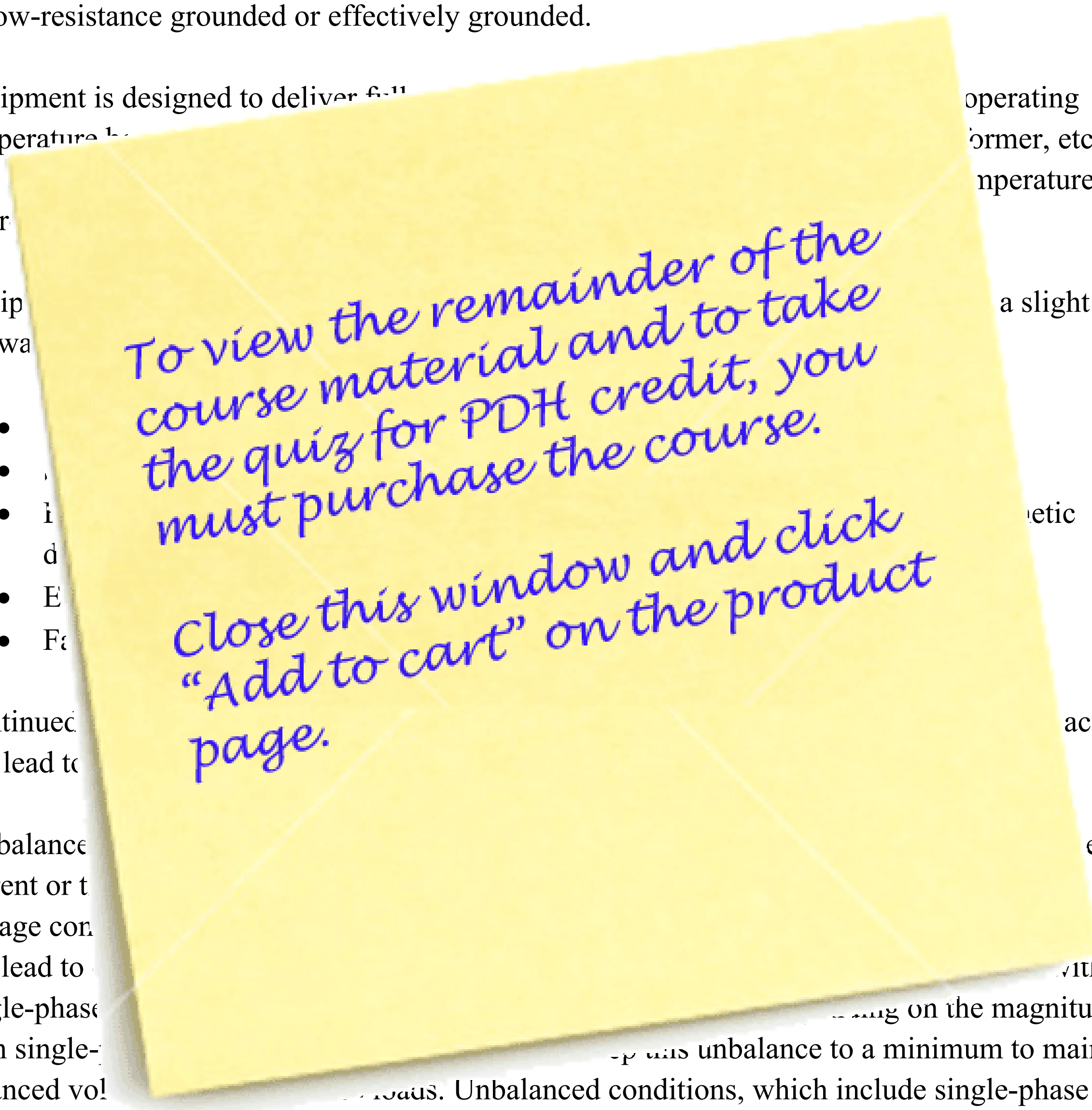
On balance ... e current or t ... voltage con ... rents can lead to ... with single-phase ... on the magnitude of each single- ... unbalance to a minimum to maintain balanced vo ... loads. Unbalanced conditions, which include single-phase and double-phase faults with or without ground, can be detected with the use of negative and zero sequence relay elements.



Abnormal frequencies can occur when the load does not equal the generation. The frequency may be above or below the system's normal frequency. Many devices, such as electronic equipment, synchronous motors, etc., are frequency sensitive.

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