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POWER SYSTEM PROTECTION

Pankaj Danodia[1] , Dayavanti Sisodia2

Visvesvaraya National Institute of Technology Nagpur (NIT) ,India[1]

pankajdanodia@gmail.com

ABSTRACT

Power system protection is the process of making the production, transmission, and consumption of electrical energy as safe as possible from the effects of failures and events that place the power system at risk. It is cost prohibitive to make power systems 100 percent safe or 100 percent reliable. Risk assessments are necessary for determining acceptable levels of danger from injury or cost resulting from damage. Protective relays are electronic or electromechanical devices that are designed to protect equipment and limit injury caused by electrical failures. Unless otherwise noted, the generic term relay will be synonymous with the term protective relay throughout this text. Relays are only one part of power system protection, because protection must be designed into all aspects of power system facilities. Protective relays cannot prevent faults; they can only limit the damage caused by faults. A fault is any condition that causes abnormal operation for the power system or equipment serving the power system. Faults include but are not limited to: short- or low-impedance circuits, open circuits, power swings, over voltages, elevated temperature, off-nominal frequency operation, and failure to operate.

Power system protection must determine from measurements of currents and/or voltages whether the power system is operating correctly. Three elements are critical for protective relays to be effective: measurements, data processing, and control.. This example system contains a single source that is connected to bus S through a step-up transformer, two transmission lines that connect bus S to bus R, and a load that is connected to bus R through a step-down transformer.

1. Goals of Protection

Maintain the Ability to Deliver Electric Power

Power systems that have evolved in the 20th century consist of generation plants, transmission facilities, distribution lines, and customer loads, all connected through complex electrical networks. In the United States, electrical energy is generated and distributed by a combination of private and public utilities that operate in interconnected grids, commonly called power pools, for reliability and marketing.

Interconnection improves the reliability of each pool member utility because loss of generation is usually quickly made up from other utilities. However, interconnection also increases the complexity of power networks. Power pool reliability is a function of the reliability of the transmission in the individual members. Protection security and dependability is significant in determining the reliability of electrical service for both individual utilities and the interconnected power system pool.

1.1Public Safety

Relays are designed to deenergize faulted sections as quickly as possible, based on the premise that the longer the power system operates in a faulted condition, the greater the chance that people will be harmed or equipment damaged. In some cases power system stability and government regulatory commissions set the speed requirements of extra high voltage (EHV) systems. Because of cost constraints, relays are not designed to prevent the deaths of people or animals who make direct contact with high voltage lines. Instead, designers use physical separation and insulation to prevent direct contact. Still, the faster a faulted system element can be detected, isolated, and deenergized, the lower the probability that anyone will encounter hazardous voltages.

1.2Equipment Protection

The primary function of power system protection is to limit damage to power system apparatus. Whether the fault or abnormal condition exposes the equipment to excessive voltages or excessive currents, shorter fault times will limit the amount of stress or damage that occurs. The challenge for protective relays is to extract information from the voltage and current instrumentation that indicates that equipment is operating incorrectly. Although different faults require different fault detection algorithms, the instrumentation remains the same, namely voltages and currents. (See Table 4.1 in Section 0 for a more complete list of instrumentation requirements.)

1.3Power System Integrity

Properly operating relay systems isolate only the portions on the network directly involved with the fault. If relays operate too quickly or fail to operate, the fault-affected area expands and some circuits are deenergized. Parts of the power system can become isolated from the rest of the network. A large mismatch between generation and load can put an islanded network in jeopardy of losing the generation control that holds frequency and voltage within acceptable limits. Without generation control, the isolated systems will eventually be tripped off by other relays.

Protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults. For this reason, the technology and philosophies utilized in protection schemes can often be old and well-established because they must be very reliable.

2.Types of protection

2.1 Generator sets – In a power plant, the protective relays are intended to prevent damage to alternators or to the transformers in case of abnormal conditions of operation, due to internal failures, as well as insulating failures or regulation malfunctions. Such failures are unusual, so the protective relays have to operate very rarely. If a protective relay fails to detect a fault, the resulting damage to the alternator or to the transformer might require costly equipment repairs or replacement, as well as income loss from the inability to produce and sell energy.

2.2 High voltage transmission network – Protection on the transmission and distribution serves two functions: Protection of plant and protection of the public (including employees). At a basic level, protection looks to disconnect equipment which experience an overload or a short to earth. Some items in substations such as transformers might require additional protection based on temperature or gas pressure, among others.

2.3 Overload & Back-up for Distance (Over current) – Overload protection requires a current transformer which simply measures the current in a circuit.
There are two types of overload protection:
A. Instantaneous overcurrent
B. Time overcurrent (TOC).

Instantaneous overcurrent requires that the current exceeds a pre-determined level for the circuit breaker to operate. TOC protection operates based on a current vs time curve. Based on this curve if the measured current exceeds a given level for the preset amount of time, the circuit breaker or fuse will operate.

2.4 Earth fault (Ground fault in the United States) – Earth fault protection again requires current transformers and senses an imbalance in a three-phase circuit. Normally the three phase currents are in balance, i.e. roughly equal in magnitude. If one or two phases become connected to earth via a low impedance path, their magnitudes will increase dramatically, as will current imbalance. If this imbalance exceeds a pre-determined value, a circuit breaker should operate.

2.5 Distance (Impedance Relay)– Distance protection detects both voltage and current. A fault on a circuit will generally create a sag in the voltage level. If the ratio of voltage to current measured at the relay terminals, which equates to an impedance, lands within a pre-determined level the circuit breaker will operate. This is useful for reasonable length lines, lines longer than 10 **miles, because its operating characteristics are based on the line characteristics. This means that when a fault appears on the line the impedance setting in the relay is compared to the apparent impedance of the line from the relay terminals to the fault. If the relay setting is determined to be below the apparent impedance it is determined that the fault is within the zone of protection. When the transmission line length is too short, less than 10 miles, distance protection becomes more difficult to coordinate. In these instances the best choice of protection is current differential protection.**

2.6 Back-up – The objective of protection is to remove only the affected portion of plant and nothing else. A circuit breaker or protection relay may fail to operate. In important systems, a failure of primary protection will usually result in the operation of back-up protection. Remote back-up protection will generally remove both the affected and unaffected items of plant to clear the fault. Local back-up protection will remove the affected items of the plant to clear the fault.

2.7 Low-voltage networks – The low voltage network generally relies upon fuses or low-voltage circuit breakers to remove both overload and earth faults.

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