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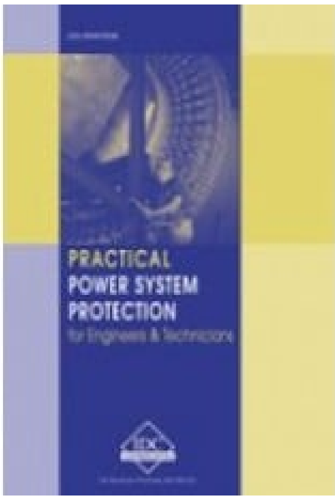
PS-E - Power Systems Protection



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Short Description

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This manual will give plant operators, electricians, field technicians and engineers a better appreciation of the role played by power system protection systems. An understanding of power systems along with correct management will increase your plant efficiency and performance as well as increasing safety for all concerned.

The manual is designed to provide excellent understanding on both a theoretical and practical level. Starting at a basic level and then moving onto more detailed applications, it features an introduction covering the need for protection, fault types and their effects, simple calculations of short circuit currents and system earthing.

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Need for protection

1 Need for protection

Important notes

1. This book was originally written for UK and other European users and contains many references to the products and standards in those countries. We have made an effort to include IEEE/ANSI/NEMA references wherever possible. The general protection approach and theoretical principles are however universally applicable.
2. The terms '*earth'*as well as '*ground'* have both been in general use to describe the common power/signal reference point interchangeably around the world in the Electro-technical terminology. While the USA and other North American countries favor the use of the term *'ground'*, European countries including UK and many other Eastern countries prefer the term *'earth'*. In this book, we will adopt the term *'ground'* to denote the common electrical reference point. Our sincere apologies to those readers who would have preferred the use of '*earth'* to the term '*ground*'.

1.1 Need for protective apparatus

A power system must be not only capable of meeting the present load but also requires the flexibility to meet the future demand. A power system is designed to generate electric power in sufficient quantity, to meet the present and estimated future demands of the users in a particular area, to transmit it to the areas where it will be used and then distribute it within that area, on a continuous basis.

To ensure the maximum return on the significant investment in the equipment, which goes to make up the power system, and to keep the users satisfied with reliable service, the whole system must be kept in operation continuously without major breakdowns.

This can be achieved in two ways:

- The first option is to implement a system using components, which should not fail and which require minimal maintenance to maintain the continuity of service. However, implementing such a system is neither economical nor feasible, except for small systems.

- The second option is to anticipate any possible effects or failures that may cause a long-term shutdown of a system, which in turn may take a longer time to bring the system back to its normal operation. The main idea is to restrict the disturbances during such failures to a limited area and maintain power distribution to the remaining areas. Special equipment is normally installed to detect such kind of failures (also called ‘faults’) that can possibly happen in various sections of a system, and to isolate faulty sections so that the interruption is limited to a localized area. The special equipment adopted to detect such possible faults is referred to as ‘Protective equipment or a protective relay’ and the system that uses such equipment is termed a ‘Protection system’.

A protective relay is the device, which gives instruction to disconnect a faulty part of the system. This action ensures that the remaining system is still fed with power, and protects the system from further damage due to the fault.

Hence, use of protective apparatus is very necessary in the electrical systems, which are expected to generate, transmit and distribute power with least interruptions and restoration time.

1.2 Basic requirements of protection

A protection system has three main functions/duties:

- Safeguard the entire system to maintain continuity of supply.
- Minimize damage and repair costs where it senses a fault.
- Ensure safety of personnel.

These requirements are necessary, firstly for early detection and localization of faults and secondly, prompt removal of faulty equipment from service.

In order to carry out the above duties, protection must have the following qualities:

1. a) ***Selectivity:*** To detect and isolate the faulty item only.
2. b) ***Stability:*** To leave all healthy circuits intact to ensure continuity of supply.
3. c) ***Sensitivity:*** To detect even the smallest fault, current or system abnormalities and operate correctly at its setting before the fault causes irreparable damage.

4. d) ***Speed:*** To operate speedily when it is called upon to do so, thereby minimizing damage to the surroundings and ensuring safety to personnel.

To meet all of the above requirements, protection must be reliable which means it must be:

- *Dependable* - it <u>must</u>trip when called upon to do so.
- *Secure* - it must <u>not</u>trip when it is not supposed to.

1.3 Basic components of protection

The protection of any distribution system is a function of many elements and this section gives a brief outline of the various components that go into protecting a system. The following are the main components of a protection system.

- A fuse self destructs and carries the currents in a power circuit continuously and sacrifices itself by blowing under abnormal conditions. These are normally independent OR stand-alone protective components in an electrical system unlike a circuit breaker, which necessarily requires the support of external components.
- Accurate protection cannot be achieved without properly measuring the normal and abnormal conditions of a system. In electrical systems, voltage and current measurements give feedback on whether a system is healthy or not. Voltage transformers and current transformers measure these basic parameters and are capable of providing accurate measurement during fault conditions without failure.
- The measured values are converted into analog and/or digital signals and are made to operate the relays, which in turn isolate the circuits by opening the faulty circuits. In most of the cases, the relays provide two functions viz., alarm and trip; once the abnormality is noticed. The relays in earlier times had very limited functions and were quite bulky. However, with the advancement in digital technology and use of microprocessors, relays monitor various parameters, which give a complete history of a system during both pre-fault and post-fault conditions.
- The opening of faulty circuits requires some time, typically milliseconds. However, the circuit breakers, which are used to isolate the faulty circuits, are capable of carrying these fault currents until the fault currents are totally cleared. The circuit breakers are the main isolating devices in a distribution system, which can be said to directly protect the system.
- The operation of relays and breakers require power sources, which shall not be affected by faults in the main distribution. Hence, the other

component, which is vital in protective system, are batteries that are used to ensure uninterrupted power to relays and breaker coils.

The above items are extensively used in any protective system and their design requires careful study and selection for proper operation.

1.4 Summary

Power system protection-main functions

1. To safeguard the entire system to maintain continuity of supply.

2. To minimize damage and repair costs.

3. To ensure safety of personnel.

Power system protection-basic requirements

1. Selectivity: To detect and isolate the faulty item only.

2. Stability: To leave all healthy circuits intact to ensure continuity of supply.

3. Speed: To operate as fast as possible when called upon, to minimize damage, production downtime and ensure safety to personnel.

4. Sensitivity: To detect even the smallest fault, current or system abnormalities and operate correctly at its setting.

Power system protection-speed is vital!!

The protective system should act fast to isolate faulty sections to prevent:

- Increased damage at fault location. Fault energy = $I^2 ´ R_f ´ t$, where t is time in seconds.

- Danger to the operating personnel (flashes due to high fault energy sustaining for a long time).

- Danger of igniting combustible gas in hazardous areas, such as methane in coal mines which could cause horrendous disaster.

- Increased probability of ground faults spreading to healthy phases.

· Higher mechanical and thermal stressing of all items of plant carrying the fault current, particularly transformers whose windings suffer progressive and cumulative deterioration because of the enormous electro-mechanical forces caused by multiphase faults proportional to the square of the fault current.

· Sustained voltage dips resulting in motor (and generator), instability leading to extensive shutdown at the plant concerned and possibly other nearby plants connected to the system.

Power system protection-qualities

1) ***Dependability:*** It MUST trip when called upon.

2) ***Security:*** It must NOT trip when not supposed to.

Power system protection-basic components

1. Voltage transformers and current transformers–To monitor and give accurate feedback about the healthiness of a system.

2. Relays–To convert the signals from the monitoring devices, and give instructions to open a circuit under faulty conditions or to give alarms when the equipment being protected, is approaching towards possible destruction.

3. Fuses–Self-destructing to save the downstream equipment being protected.

4. Circuit breakers–These are used to make circuits carrying enormous currents, and also to break the circuit carrying the fault currents for a few cycles based on feedback from the relays.

5. DC batteries–These give uninterrupted power source to the relays and breakers that is independent of the main power source being protected.