FINAL YEAR PROJECT REPORT

(PLC BASED TRANSFORMER PROTECTION)

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Acknowledgements

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Abstract

Engineering is not only a theoretical study but is implementation of all we study for creating something new and making things more easy and useful through practical study.

It is an art which can be gained with systematic study, observation and practice. In the college curriculum we usually get the theoretical knowledge of the industries, and a little bit of implementation knowledge that how it works? But how can we prove our practical knowledge to increase the productivity or efficiency of the industry?

Power system protection is a branch of electrical power engineering that deals with the 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. Current transformers and voltage transformers form a very important link between the Power system and the protective system. These transducers basically extract the information regarding current and voltage from the power system under protection and pass it on to the protective relays. While doing this, they insulate the low voltage protective system (both personnel and protective apparatus) from the high voltage power system.

DEDICATION

Dedicated to ALLAH, Who bestowed us with the ability to understand His knowledge to serve this world and our parents, teachers and friends, without their support it would not have been possible to complete this project.

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INTRODUCTION TO POWER SYSTEM PROTECTION

1.1. INTRODUCTION

Power system protection is a branch of electrical power engineering that deals with the 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.

1.2 ZONES OF PROTECTION

To limit the extent of the power system that is disconnected when a fault occurs, protection is arranged in zones. The principle is shown in Figure 1.2. Ideally, the zones of protection should overlap, so that no part of the power system is left unprotected. This is shown in Figure 1.3, the circuit breaker being included in both zones.

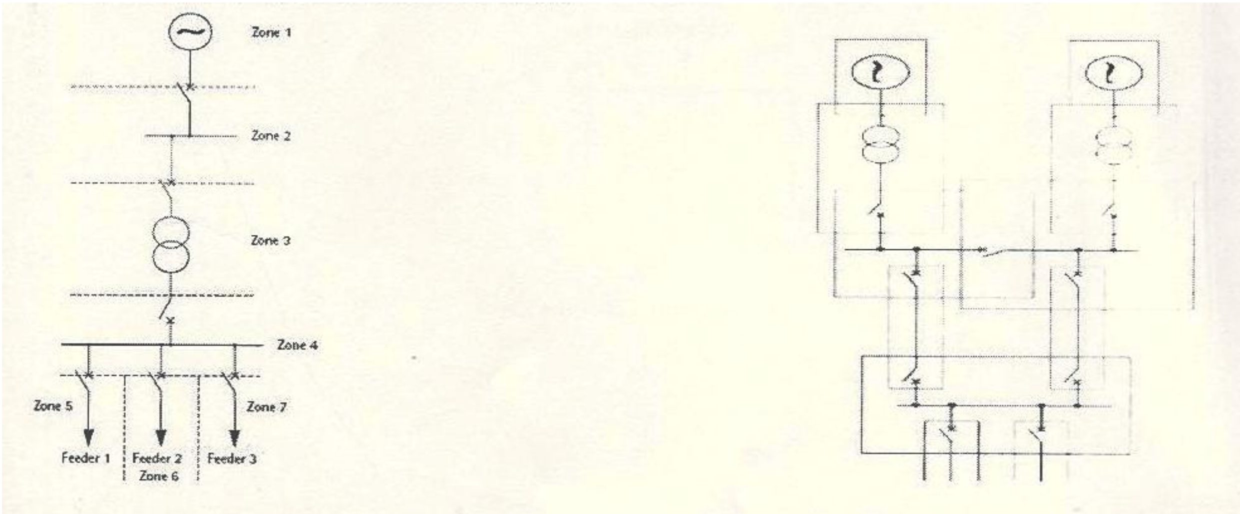

Figure 1.1

Zone 1 is an under reaching zone and is generally set at 85-90% of line length to be protected. Zone 2 is an overreaching zone set at 120-150% of the line. The coordination delay for zone 2 is usually of the order of 0.3s.Zone 3 provides an overall backup for the line and is set at 120-180% of the line. The third zone must coordinate in time and distance with other zones and it is normally set at 1s.

1.3 A PROTECTION SYSTEM AND ITS ATTRIBUTES

1.3.1 SELECTIVITY

When a fault occurs, the protection scheme is required to trip only those circuit breakers whose operation is required to isolate the fault. This property of selective tripping is also called ‘discrimination’ and is achieved by two general methods.

A. TIME GRADING:

Protection systems in successive zones are arranged to operate in times that are graded through the sequence of equipments so that upon the occurrence of a fault, although a number of protection equipments respond, only those relevant to the faulty zone complete the tripping function. The others make incomplete operations and then reset. The speed of response will often depend on the severity of the fault, and will generally be slower than for a unit system.

B. UNIT SYSTEMS:

It is possible to design protection systems that respond only to fault conditions occurring within a clearly defined zone. This type of protection system is known as 'unit protection'. Certain types of unit protection are known by specific names, e.g. restricted earth fault and differential protec1in Unit protection can be applied throughout a power system and, since it does not involve time grading, is relatively fast in operation. The speed of response is substantially independent of fault severity. Unit protection usually involves comparison of quantities at the boundaries of the protected zone as defined by the locations of the current transformers. This comparison may be achieved by direct hardwired connections or may be achieved via a communication link. However certain protection systems derive their 'restricted' property from the configuration of the power system and may be classed as unit protection, e.g. earth fault protection applied to the high voltage delta winding of a power transformer. Whichever method is used, it must be kept in mind that selectivity is not merely a matter of relay design. It also depends on the correct coordination of current transformers and relays with a suitable choice of relay settings, taking into account the possible range of such variables as fault currents, maximum load current, system impedances and other related factors, where appropriate.

1.3.2 STABILITY

The term 'stability' is usually associated with unit protection schemes and refers to the ability, of the protection system to remain unaffected by conditions external to the protected zone, for example through load current and external fault conditions.

1.3.3 SPEED

The function of protection systems is to isolate faults on the power system as rapidly as possible. The main objective is to safeguard continuity of supply by removing each disturbance before it leads to widespread loss of synchronism and consequent collapse of the power system. As the loading on a power system increases, the phase shift between voltages at different bus bars on the system also increases, and therefore so does the probability that synchronism will be lost when the system is disturbed by a fault. The shorter the time a fault is allowed to remain in the system, the greater can be the loading of the system. Figure 1.2 shows typical relations between system loading and fault clearance times for various types of fault. It will be noted that phase faults have a more marked effect on the stability of the system than a simple earth fault and therefore require faster clearance.

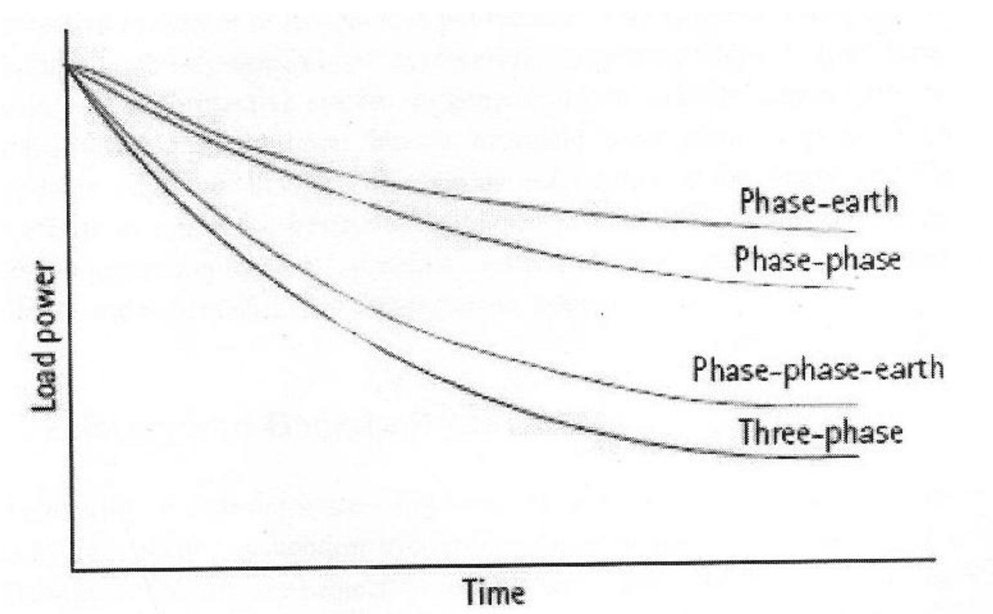

Figure 1.2

System stability is not, however, the only consideration. Rapid operation of protection ensures that fault damage is minimized, as energy liberated during a fault is proportional to the square of the fault current times the duration of the fault. Protection must thus operate as quickly as possible but speed of operation must be weighed against economy. Distribution circuits, which do not normally require a fast fault clearance, are usually protected by time-graded system. Generating plant and EHV systems require protection gear of the highest attainable speed: the only limiting factor will be the necessity for correct operation, and therefore unit systems are normal practice.

1.3.4 SENSITIVITY

Sensitivity is a term frequently used when referring to the minimum operating level (current, voltage, power etc.) of relays or complete protection schemes. The relay or scheme is said to be sensitive if the primary operating parameters is low. With older electromechanical relays, sensitivity was considered in terms of the sensitivity of the measuring movement and was measured in terms of its volt-ampere consumption to cause operation. With modern digital and numerical relays the achievable sensitivity is seldom limited by the device design hut by its application and CT/VT parameters.

1.3.5 RELIABILITY AND DEPENDABILITY

A protective system is of no use if is not reliable. There are many ways in which reliability can be built into the system. Good engineering judgment plays a great part in enhancing the reliability of the protective system. In general, it is found that simple systems are more reliable. Systems which depend upon locally available information tend to be more reliable and dependable than those that depend upon the information at the remote end. However, in spite of best efforts to make the system reliable, we cannot rule out the possibility of failure of the (primary) protection system. Therefore, we add features like back up protection to enhance the reliability and dependability of the protective system.

1.4 TYPES OF PROTECTION:

1.4.1 GENERATOR SETS:

In a power plant, the protective relays are intended to prevent damage to alternators or of 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 damage to the alternator or to the transformer may have important financial consequences for the repair or replacement of equipment and the value of the energy that otherwise would have been sold.

1.4.2 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 connection to earth. Some items in substations such as transformers may require additional protection based on temperature or gassing among others.

1.4.3 OVERLOAD:

Overload protection requires a current transformer which simply measures the current in a circuit. If this current exceeds a pre-determined level, a circuit breaker or fuse should operate.

1.4.4 EARTH FAULT:

Earth fault protection again requires current transformers and senses an imbalance in a three-phase circuit. Normally a three-phase circuit is in balance, so if a single (or multiple) phases are connected to earth an imbalance in current is detected. If this imbalance exceeds a pre-determined value a circuit breaker should operate.

1.4.5 DISTANCE:

Distance protection detects both voltage and current. A fault on a circuit will generally create a sag in the voltage level. If this voltage falls below a predetermined level and the current is above a certain level the circuit breaker should operate. This is useful on long lines where if a fault was experienced at the end of the line the impedance of the line itself may inhibit the rise in current. Since voltage sag is required to trigger the protection the current level can actually be set below the normal load on the line.

1.4.6 BACK-UP:

At all times the objective of protection is to remove only the affected portion of plant and nothing else. Sometimes this does not occur for various reasons which can include:

- Mechanical failure of a circuit breaker to operate
- Incorrect protection setting
- Relay failures

A failure of primary protection will usually result in the operation of back-up protection which will generally remove both the affected and unaffected items of plant to remove the fault.

1.4.7 LOW-VOLTAGE NETWORKS:

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

1.5 FAULTS:

In power system engineering, any abnormality that can cause damage to a system is termed as fault. If a fault affects all the phases equally then it is termed as balanced fault, otherwise, it is n unbalanced fault.

1.5.1 TYPES OF FAULTS ON A THREE PHASE SYSTEM:

Different faults as shown in figure 1.3 are discussed below

A. Phase-to-earth fault
B. Phase-to-phase fault
C. Phase-to-phase-to-earth fault
D. Three phase fault
E. Three phase-to-earth fault
F. Phase-to-pilot fault
G. Pilot-to-earth fault

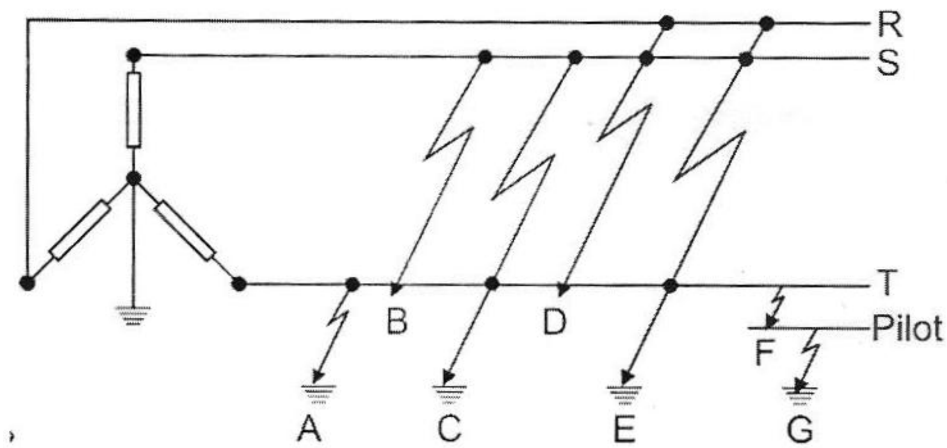

Figure 1.3

It will be noted that for a phase-to-phase fault, the currents will be high, because the fault current is only limited by the inherent (natural) series impedance of the power system up to the point of fault.

By design, this inherent series impedance in a power system is purposely chosen to be as low as possible in order to get maximum power transfer to the consumer and limit unnecessary losses in the network itself in the interests of efficiency.

On the other hand, the magnitude of earth faults currents will be determined by the manner in which the system neutral is earthed. Solid neutral earthing means high earth fault currents as this is only limited by the inherent earth fault (zero sequence) impedance of the system.

It is worth noting at this juncture that it is possible to control the level of earth fault current that can flow by the judicious choice of earthing arrangements for the neutral.

In other words, by the use of Resistance or Impedance in the neutral of the system, earth fault currents can be engineered to be at whatever level is desired and are therefore controllable. This cannot be achieved for phase faults.

1.5.2 SYMMETRICAL & ASYMMETRICAL FAULTS:

A symmetrical fault is a balanced fault with the sinusoidal waves being equal about their axes, and represents a steady state condition.

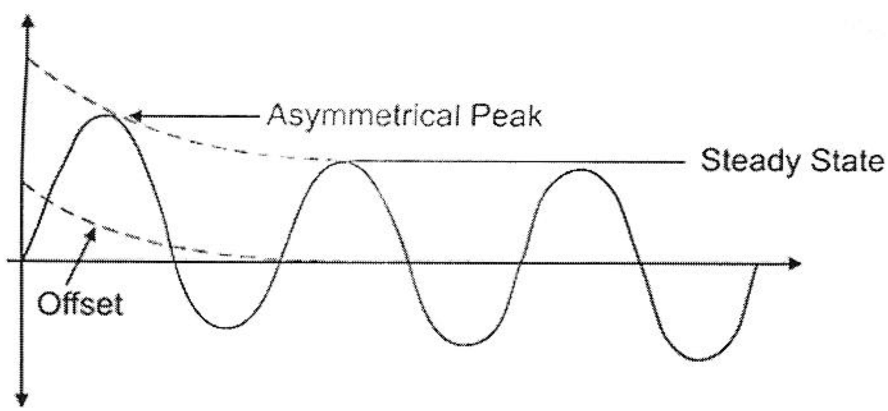

Figure 1.4

An asymmetrical fault displays a D.C. offset, transient in nature and decaying to the steady state of the symmetrical fault after a period of time.

1.5.2.1 ASYMMETRIC FAULT:

In power engineering, specifically three phase power, an asymmetric or unbalanced fault is a fault which does not affect each of the three phases equally. This is in contrast to a symmetric fault, where each of the phases is affected equally. In practice, most faults in power systems are unbalanced; however, as asymmetric faults are difficult to analyze, analysis of asymmetric faults is built up from a thorough understanding of symmetric faults.

Common types of asymmetric faults, and their causes:

- Line-to-line - a short circuit between lines, caused by ionization of air, or when lines come into physical contact, for example due to a broken insulator.
- line-to-ground - a short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other storm damage
- double line-to-ground - two lines come into contact with the ground (and each other), also commonly due to storm damage

An asymmetric fault breaks the underlying assumptions used in three phase power, namely that the load is balanced on all three phases. Consequently, it is impossible to directly use tools such as the one-line diagram, where only one phase is considered. However, due to the linearity of power systems, it is usual to consider the resulting voltages and currents as a superposition of symmetrical components, to which three phase analysis can be applied.

The method of symmetric components is perhaps somewhat unintuitive, but can be verified to give correct results. The power system is seen as a superposition of three components:

- a positive-sequence component, in which the phases are in the same order as the original system, i.e. a-b-c
- a negative-sequence component, in which the phases are in the opposite order as the original system, i.e. a-c-b
- A zero-sequence component, which is not truly a three phase system, but instead all three phases are in phase with each other.

To determine the currents resulting from an asymmetrical fault, one must first know the per-unit zero-, positive-, and negative-sequence impedances of the transmission lines, generators, and transformers involved. Three separate circuits are then constructed using these impedances. The individual circuits are then connected together in a particular arrangement that depends upon the type of fault being studied. Once the sequence circuits are properly connected, the network can then be analyzed using classical circuit analysis techniques.

1.5.2.2 SYMMETRIC FAULT:

In power engineering, specifically three-phase power, a symmetric, symmetrical or balanced fault is a fault which affects each of the three-phases equally. In transmission line faults, roughly 5% are symmetric. This is in contrast to an asymmetric fault, where the three phases are not affected equally. In practice, most faults in power systems are unbalanced. With this in mind, symmetric faults can be viewed as somewhat of an abstraction; however, as asymmetric faults are difficult to analyze, analysis of asymmetric faults is built up from a thorough understanding of symmetric faults.

Symmetric faults can be analyzed via the same methods as any other phenomena in power systems, and in fact many software tools exist to accomplish this type of analysis automatically. However, there is another method which is as accurate and is usually more instructive.

First, some simplifying assumptions are made. It is assumed that all electrical generators in the system are in phase, and operating at the nominal voltage of the system. Electric motors can also be considered to be generators, because when a fault occurs, they usually supply rather than draw power. The voltages and currents are then calculated for this base case.

Next, the location of the fault is considered to be supplied with a negative voltage source, equal to the voltage at that location in the base case, while all other sources are set to zero. This method makes use of the principle of superposition.

To obtain a more accurate result, these calculations should be performed separately for three separate time ranges:

- sub transient is first, and is associated with the largest currents
- transient comes between sub transient and steady-state
- steady-state occurs after all the transients have had time to settle

The most common types of fault are single-line-to-ground fault, line-to-line fault, and double-line-to-ground fault. All of these are unbalanced faults. The balanced (or three phase) fault is the one when all three lines are shorted to ground. It is usually rare, but can happen. When a fault occurs it is important to isolate it by opening protective breakers. To properly set the breakers, the magnitude of the fault currents needs to be known.

The life of a fault can be divided into the following times which occur in sequence:

1. The sub-transient period which lasts for only a few cycles?
2. The transient period which lasts for a much longer period (tens of cycles)
3. The steady state period which lasts till a major change in the transmission network takes place (like a circuit breaker opening or a line failing)

It is not practical to design and build electrical equipment or networks so as to completely eliminate the possibility of failure in service. It is therefore an everyday fact of life that different types of faults occur on electrical systems, however infrequently, and at random locations.

Faults can be broadly classified into two main areas which have been designated “Active” and “Passive”.

1.5.3 ACTIVE FAULTS:

The “Active” fault is when actual current flows from one phase conductor to another (phase-to-phase) or alternatively from one phase conductor to earth (phase-to-earth).

This type of fault can also be further classified into two areas, namely the “solid” fault and the ‘incipient” fault.

The solid fault occurs as a result of an immediate complete breakdown of insulation as would happen if, says. A pick struck an underground cable, bridging conductors etc, or the cable was dug up by a bulldozer. In mining, a rock fall could crush a cable as would a shuttle car. In these circumstances the fault current would be very high, resulting in an electrical explosion. This type of fault must be cleared as quickly as possible, otherwise there will be:

Greatly increased damage at the fault location. (Fault energy = 12 x Rfx t where t is time). Danger to operating personnel (Flash products).

Danger of igniting combustible gas such as methane in hazardous areas giving rise to a disaster of horrendous proportions.

Increased probability of earth faults spreading to other phases.

Higher mechanical and thermal stressing of all items of plant carrying the current fault. (Particularly transformers whose windings suffer progressive and cumulative deterioration because of the enormous electromechanical forces caused by multi-phase faults proportional to the current squared). Sustained voltage dips resulting in motor (and generator) instability leading to extensive shut-down at the plant concerned and possibly other nearby plants.

The “incipient” fault, on the other hand, is a fault that starts from very small beginnings, from says some partial discharge (excessive electronic activity often referred to as Corona) in a void in the insulation, increasing and developing over an extended period, until such time as it burns away adjacent insulation, eventually running away and developing into a “solid” fault.

Other causes can typically be a high-resistance joint or contact, alternatively pollution of insulators causing tracking across their surface. Once tracking occurs, any surrounding air will ionize which then behaves like a solid conductor consequently creating a “solid” fault.

1.5.3.1 PASSIVE FAULTS:

Passive faults are not real faults in the true sense of the word but are rather conditions that are stressing the system beyond its design capacity, so that ultimately active faults will occur.

Typical examples are:

Overloading - leading to overheating of insulation (deteriorating quality, reduced life and ultimate failure).

Overvoltage - stressing the insulation beyond its limits.

Under frequency - causing plant to behave incorrectly.

Power swings - generators going out-of-step or synchronism with each other.

It is therefore very necessary to also protect against these conditions.

1.5.4 TRANSIENT & PERMANENT FAULTS:

Transient faults are faults which do not damage the insulation permanently and allow the circuit to be safely re-energized after a short period of time.

A typical example would be an insulator flashover following a lightning strike, which would be successfully cleared on opening of the circuit breaker. Transient faults occur mainly on outdoor equipment where air is the main insulating medium. Permanent faults, as the name implies, are the result of permanent damage to the insulation. In this case, the equipment has to be repaired and reclosing must not be entertained.