# A Review of PHCN Protection Schemes

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## ABSTRACT

This paper brings to the fore, a comprehensive and useful guide to the concepts, practices, and equipment in the important field of Electrical (protection) Engineering. The PHCN Power network experiences several types of fault like over/under voltage, overload, earth fault etc. and as a result of these faults, proper protection is necessary for efficiency and continuity of supply. Components of protection and the various protection schemes as well as their guiding principles as it relates to old method of protection employed by PHCN and the latest improvements are also considered.

This paper also sheds light on the protection of PHCN networks from generation, transmission and distribution, also considered is the protection of transformers, busbars, transmission lines, overhead lines, generating generators and feeders. It is anticipated that this work will be of immense benefit to those concerned with design, planning, construction and operation especially in the area of protection.

(**Keywords:** Protection, PHCN, Continuity, Schemes)

## 1.0 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 faults, whilst having as much of the network as possible still in operation.

This present effort deals with the relevant aspects of protection in recent Nigeria practice in Power Holding Company of Nigeria (PHCN) for generation, transmission and distribution systems.

The purpose of this paper therefore is to provide the background knowledge necessary for a proper understanding of aims and the role of protection in power systems with special reference to PHCN.

The word "Protection" is used here to describe the whole concept of protection of a power system.

## 2.0 THE ROLE OF PROTECTION IN A POWER SYSTEM

It is fair to say that without discriminative protection, it would be impossible to operate a modern power system. The protection is needed to remove, as speedily as possible, any element of the power system in which a fault has developed. So long as the fault remains connected, the whole system may be in jeopardy from three main effects of the fault, these are

a. It is likely to cause the individual generators in a power station or group of generators in different stations to lose synchronism and fall out of step with consequent spitting of the system.

b. There is a risk of damage to the affected plant

c. A risk of damage to healthy plants.

There is another effect, not necessarily dangerous to the system but important from the consumers' viewpoint namely; the risk of synchronous motor in large industrial premises falling out of step and tripping out, with the serious consequences that entail loss of production and interruption of vital processes. It is the function of the protective equipment, in association with the circuit breakers, to avert these effects.

## 3.0 THE NEED FOR PROTECTION OF EQUIPMENT

The huge capital investment involved in a power system for generation, transmission and distribution of electrical power is so great that proper precaution must be ensured so that

a. The equipment operates as nearly as is possible at its peak efficiency.
b. The equipment is protected; faults and damages to equipment are prevented or minimized.
c. Accidents to life are properly avoided
d. System instability is prevented
e. Continuity and quality of service is maintained
f. Service outages are minimized.

## 4.0 COMPONENTS OF PROTECTION SYSTEM

Protection systems usually comprise five major components:

a. Current and voltage transformers to step up currents and to step down the high voltages respectively of the electrical power system to convenient levels for the relays to deal with.

b. Relays to sense the fault and initiate a trip or disconnection.

c. Circuit breakers to open/close the systems based on relay and auto-recloser commands.

d. Batteries to provide power in case of power disconnection in the system.

e. Communication channels to allow analysis of current and voltage at remote terminals of a line and to allow remote tripping of equipment.

For parts of a distribution system, fuses are capable of both sensing and disconnecting faults.

Failures may occur in each part, such as insulation failure, fallen or broken transmission lines, incorrect operation of circuit breakers, short-circuit and open-circuits. Protective devices are installed with the aim of protection of assets and to ensure continued supply of energy. The three classes of protective devices are:

i. Protective relays which control the tripping of the circuit breakers surrounding the faulted part of the network.

ii. Automatic operation, such as auto-reclosing or system restart.

iii. Monitoring equipment which collects data on the system for post event analysis.



While the operating quality of these devices and especially of the protective relays is always critical, different strategies are considered for protecting the different parts of the system.

Very important equipment may have completely redundant and independent protective systems, while a minor branch distribution line may have very simple low-cost protection.

## 5.0 COMPONENTS OF PHCN PROTECTIVE SCHEMES

Components of PHCN protective schemes include the followings:

(a) Circuit breakers

(b) Transducers such as VTs and CTs

(c) Relays, which are of two major types viz:

i. Electromechanical – solenoid and induction type

ii. Electronic such as discrete components, integrated circuits, computers.

(d) Communication Links between ends of protected equipment such as

i. Private pilot wires which comprise auxiliary wires in addition to power conductors.

ii. Rented pilot circuits

iii. Radio links

iv. Superimposed signals on power conductors (power line carrier, PLC.)

(e) Couplers

## 6.0 PHCN TRANSFORMER FAULTS

The transformers used by PHCN are often times faced with a number of faults which include

- **Faults within the transformer tank:** These may comprise phase-to-earth, phase-to-phase, or interturn faults on the windings, interwinding faults, tap changer faults, insulator bushing failure and core overheating due to failure of core insulation.
- **Faults on Transformer Connections:** These may comprise any type of normal system fault on open copper work connections or flashover of coordinating gaps. Faults between the current transformers and the associated circuit breaker have to be included in this category.
- **Overheating:** Failure of the cooling system will cause overheating and consequent danger of damage to the windings.
- **Faults external to the Transformer Zone:** These will be of the usual range of system earth and phase faults to be cleared by appropriate external protection systems. They will affect, therefore, only the requirement of transformer back up protection.



## 7.0 CAUSES OF INTERNAL AND EXTERNAL ELECTRICAL FAULTS IN PHCN TRANSFORMERS

Before considering, in detail, the many forms of protection fitted to PHCN transformers, it is desirable to consider the origin and effect of faults and other system disturbances so the significance of the protection arrangements may be appreciated.

There are a number of operating conditions which can be permitted to continue for limited periods but which will cause damage that will lead to breakdown and electrical fault if they persist for long periods. These conditions, which should ideally be detected before their effects become serious, are considered below. These are also conditions which will cause fault to develop quickly.

i. Operation at Frequencies above and below the Normal Frequency

ii. Mechanical Failures

iii. Over Loading

iv. Faults on Systems connected to Transformer

v. Overvoltage Operation

## 5.0 PROTECTION OF PHCN TRANSFORMERS

The protection provided for PHCN power transformers depends to some extent upon its size and rating, and will comprise a number of systems each designed to provide the requisite degree of protection for the different fault conditions.

The protective equipment used with transformers is dependent on their importance, size and ratings. Single-phase and three-phase transformers used at voltage level up to 33KV and with ratings up to 5MVA are often protected by fuses links which must in all cases be capable of carrying the maximum exciting-current surges which may occur without operating.

PHCN transformers are protected by a number of protective schemes, these include:

a. Inverse time/current relays
b. Overheat and fire protection
c. Standby earth-fault protection
d. Over fluxing protection
e. Restricted earth fault (ref) protection
f. Gas generation and oil surge protection (buchholz gas and actuated relay)
g. Current-differential schemes
h. Tank earth fault protection
i. Earth fault protection of delta-connected windings
j. Combined differential and restricted earth fault protection

## 9.0 PROTECTION OF PHCN OVERHEAD LINES, CABLES AND TRANSMISSION LINES

The Power Holding Company of Nigeria (PHCN) employs several protective schemes in order to protect the overhead lines, cables and transmission lines, prominent among the protective schemes are the schemes mention below:

(a) **Interlock protective schemes:** These protective schemes are characterized by the following features:

i. Relaying arrangements
ii. Interlocking signals
iii. Signaling channels
iv. Starting relays

A variety of interlock protective schemes have been applied to PHCN overhead lines over the years, prominent among them are

i. Modern schemes
i. Reyrolle interlock protective scheme

(b) **Phase comparison scheme:** it works on the principle that the relative phases of the line currents monitored at the two ends of a line alter when a line fault occurs anywhere between the two ends; this scheme is affected by several factors such as

I. The phase displacement of line current
II. The production of comparison signals
III. Starting relays
IV. Signaling equipment
V. The comparison process

Phase comparison schemes employed by PHCN include:

- Telephase protective schemes
- Contraphase protective schemes

(c) **Distance-time protective schemes:** these include:

i. Optimho static-distance protection schemes
ii. Distance protection relay
iii. Under-reaching distance scheme with permissive carrier intertrip

(d) **Application of current-differential protective schemes:** These schemes may be implemented in two basic forms i.e. circulating current and balanced voltage. All current differential schemes must compare the currents flowing at the two ends of their protected zones. Examples of these schemes are:

i. Comparison arrangement schemes:

For comparison purposes, two possible methods are used for producing single quantities from sets of three-phase currents, these involve Sequence network and Summation transformers.

ii. Circulating current schemes: for proper application of this scheme, the following conditions must be met:

The circuit must be physically symmetrical.

The circuit transformers must be physically identical and

The current transformer must produce identical secondary currents at each instant when they have the same currents in their primary windings.

iii. Balanced-voltage schemes
iv. The use of pilot wires.
v. Protective schemes which use rented telephone circuits.
vi. Current-differential schemes incorporating optical fibre links.

## 10. PROTECTION OF PHCN BUSBARS AND GENERATORS

a. **Busbars:** form a vital part of power networks in PHCN, because they link incoming circuits connected to sources, to outgoing circuits which feed loads. Although busbars have often been left without specific protection and this is as a result of the following reasons:

i. The busbars and switchgear have a high degree of reliability to the point of being regarded as intrinsically safe.

ii. It was feared that accidental operation of busbar protection might cause widespread dislocation of the power system, which if not quickly cleared, would cause more loss than would the very infrequent actual bus faults.

Busbar protection is that combination of c.ts and relays which are used to detect faults occurring within the busbar zone of a busbar substation and which initiate tripping of all those circuit breakers, the opening of which is necessary to isolate these faults. Busbars are protected from accidental contact either by a metal enclosure or by elevation out of normal reach.

Simple busbars used in direct-current distribution networks operating at relatively low voltages may be protected by fuses. Correct discrimination in the event of fault either on the busbars or the circuits connecting them can be achieved by selecting fuse-links with the appropriate current ratings and operating times, fuses may also be used to protect simple busbars used in single-phase distribution networks operating at relatively low voltages. Fuses are not suitable for application to three-phase busbars, however, because complete circuits would not be cleared in the event of single-phase faults and, as a result, equipment such as motors could be supplied with unbalanced voltage.

IDMT relays are used to protect the busbars of some single-phase and three-phase distribution networks, other busbar protective arrangements include:

i. The use of double-bus section protection
ii. Application to 3-phase un-sectionalized busbar (overall protection with all secondary windings connected in parallel)
iii. The use of bus section switches with two zones

b. **Generators:** Typical faults peculiar to a generator include stator, insulation fault, overload, overvoltage, unbalanced loading, rotor faults, loss of excitation, loss of synchronism, failure of prime mover, low vacuum, lubrication oil failure, loss of boiler firing, over speeding, rotor distortion, difference in expansion between rotating and stationary parts and excessive vibrations. Since it is impossible to use a single system of protection to cover the wide range/variety of fault conditions listed above, a number of protective devices are therefore necessary to cater for the followings:

i. Stator faults such as phase-earth, phase-phase, 3-phase and inter-turn.

ii. Rotor faults such as winding to earth, loss of excitation.

iii. Unbalanced loading

iv. Over-and under-voltage

v. Prime mover faults such as over speed, loss of steam pressure, loss of vacuum etc.

PHCN generator protection system includes the followings:

- Biased differential protection
- Unbiased differential protection
- Over speed protection
- Negative phase-sequences protection

- Loss of excitation (field failure) protection
- Rotor earth-fault protection
- Back-up over current and earth-fault protection
- Interturn fault protection
- Sensitive power protection

## 11. DISTRIBUTION FEEDER PROTECTION

The type of protection schemes employed to protect a feeder against fault depends on the structure of the network i.e. whether it is a radial feeder or part of a mesh network.

A radial feeder is one that is connected to a power source at only one end of the feeder, thus whenever a fault occurs on that feeder, fault current, $I_F$ always flows only in one direction i.e. from the end connected to the power source.

The protection provided for a feeder against faults could be simple IDMT overcurrent and earth fault relays for radial feeders, or more complex combinations of Distance/impedance relays and directional overcurrent relays for mesh interconnected networks.

**TABLE 1: GLOSSARY OF SOME PROTECTION RELAYS.**

| Relay | Main/Auxiliary | Function | Where mounted | Used to protect |
|---|---|---|---|---|
| Overcurrent | Main relay | To detect a current in excess of a given limit in a circuit | Indoor relay panel | Cables, transmission lines, motors and transformers |
| Overvoltage | Main | To detect voltage in excess of a given limit at a point in a circuit | Indoor relay panel | Insulation of Busbars and electrical equipments generally |
| Under voltage | Main | To detect a voltage below a given limit | Indoor relay panel | Motors and generators |
| Earth fault | Main | Overcurrent relay wired in the neutral circuit to monitor earth fault current | Indoor relay panel | Cables, transmission lines, transformers and motors |
| Buchholz | Main | To detect internal faults in power transformers through the accompanying gas bubbles or oil surge | Outdoor on the oil piping on transformer | Power transformer |
| Differential | Main | To detect faults within its zone of coverage i.e. between its two set of C.Ts | Indoor Relay | Power transformers, Busbars and generators. |
| Winding temperature; oil temperature | Main | To measure the temperature of the windings (or oil) of a power transformer | Outdoor on the body of the power transformer or in nearby kiosk | Power transformers |
| Restricted earth fault (r.e.f) | Main | To detect earth fault in particular windings of a power transformer | Indoor relay panel | Power Transformer |
| Voltage operated contactors | Auxiliary | To carry out various switching duties when its coil is energized by a main relay. Also acts as a flag indicator for other relays like the buchholz | Indoor Relay panel | |

## 12. CONCLUSION

Modern society, because of its pattern of social and working habits, has come to expect that the supply should be continuously available on demand as expected of PHCN. This is not possible due to random system failures, which are generally outside the control of power system engineers.

This paper has presented the background knowledge necessary for a proper understanding of aims and the role of protection in power systems with special reference to PHCN. The authors also elucidated the relevant aspects of protection for generation, transmission and distribution systems. This work has carefully neglected the detailed explanations of the various types of protection schemes mentioned as the treatment is beyond the scope of this endeavor.

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