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PROTECTION OF ALTERNATORS AND TRANSFORMERS

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ABSTRACT

Alternator and transformer protection often focuses on differential protection as a primary method, which compares currents entering and leaving the protected zone to detect internal faults. Other key areas of research include specific fault types like stator winding faults in alternators and transformer faults caused by short-circuits, which are addressed with various relay schemes, some modified for better sensitivity or to handle specific challenges like magnetizing inrush current. Advanced techniques such as low-frequency injection are also researched for improved stator winding protection.

Keywords: Alternator, Transformer, Stator Winding.

1. INTRODUCTION

The modern electric power system consists of several elements e.g. alternators, transformers, station bus-bars, transmission lines and other equipment. It is desirable and necessary to protect each element from a variety of fault conditions which may occur sooner or later. The protective relays discussed in the previous chapter can be profitably employed to detect the improper behavior of any circuit element and initiate corrective measures. As a matter of convenience, this chapter deals with the protection of alternators and transformers only. The most serious faults on alternators which require immediate attention are the stator winding faults. The major faults on transformers occur due to short-circuits in the transformers or their connections. The basic system used for protection against these faults is the differential relay scheme because the differential nature of measurements makes this system much more sensitive than other protective systems.

a) Protection of Alternators

1.1 Of Alternators The generating units, especially the larger ones, are relatively few in number and higher in individual cost than most other equipment's. Therefore, it is desirable and necessary to provide protection to cover the wide range of faults which may occur in the modern generating plant. Some of the important faults which may occur on an alternator are: (i) failure of prime-mover (ii) failure of field (iii) overcurrent (iv) overspeed (v) overvoltage (vi) unbalanced loading

1.2 Failure of prime-mover. When input to the prime-mover fails, the alternator runs as a synchronous motor and draws some current from the supply system. This motoring conditions is known as "inverted running". (a) In case of turbo-alternator sets, failure of steam supply may cause inverted running. If the steam supply is gradually restored, the alternator will pick up load without disturbing the system. If the steam failure is likely to be prolonged, the machine can be safely isolated by the control room attendant since this condition is relatively harmless. Therefore, automatic protection is not required. (b) In case of hydro-generator sets, protection against inverted running is achieved by providing mechanical devices on the water-wheel. When the water flow drops to an insufficient rate to maintain the electrical output, the alternator is disconnected from the system. Therefore, in this case also electrical protection is not necessary. (c) Diesel engine driven alternators, when running inverted, draw a considerable amount of power from the supply system and it is a usual practice to provide protection against motoring in order to avoid damage due to possible mechanical seizure. This is achieved by applying reverse power relays to the alternators which *isolate the latter during their motoring action. It is essential that the reverse power relays have time-delay in operation in order to prevent inadvertent tripping during system disturbances caused by faulty synchronizing and phase swinging. (ii) Failure of field. The chances of field failure of alternators are undoubtedly very rare. Even if it does occur, no immediate damage will be caused by permitting the alternator to run without a field for a short-period. It is sufficient to rely on the control room attendant to disconnect the faulty alternator manually from the system bus-bars. Therefore, it is a universal practice not to provide †automatic protection against this contingency. (iii) Overcurrent. It occurs mainly due to partial breakdown of winding insulation or due to overload on the supply system. Overcurrent protection for alternators is considered unnecessary because of the following reasons : (a) The modern tendency is to design alternators with very high values of internal impedance so that they will stand a complete short-circuit at their terminals for sufficient time without serious overheating. On the occurrence of an overload, the alternators can be disconnected manually. (b) The disadvantage of using overload protection for alternators is that such a protection might disconnect the alternators from the power plant bus on account of some momentary troubles outside the plant and, therefore, interfere with the continuity of electric service

1.3 Modified Differential Protection for Alternators

If the neutral point of a star-connected alternator is earthed through a high resistance, protection schemes shown in. 22.2 or will not provide sufficient sensitivity for earth-faults. It is because the high earthing resistance will limit the earth-fault currents to a low value, necessitating relays with low current settings if adequate portion of the generator winding is to be protected. However, too low a relay setting is undesirable for reliable stability on heavy through phase-faults. In order to overcome this difficulty, a modified form of differential protection is used in which the setting of earth faults is reduced without impairing stability. The modified arrangement is shown in Fig. 22.5. The modifications affect only the relay connections and consist in connecting two relays for phase-fault protection and the third for earth-fault protection only. The two-phase elements (PC and PA) and balancing resistance (BR) are connected in star and the earth relay (ER) is connected between this star point and the fourth wire of circulating current pilot-circuit. Operation. Under normal operating conditions, currents at the two ends of each stator winding will be equal. Therefore, there is a balanced circulating current in the phase pilot wires and no current flows through the operating coils of the relays. Consequently, the relays remain inoperative.

b) Protection of Transformers

Are static devices, totally enclosed and generally oil immersed. Therefore, chances of faults occurring on them are very rare. However, the consequences of even a rare fault may be very serious unless the transformer is quickly disconnected from the system. This necessitates to provide adequate automatic protection for transformers against possible faults. Small distribution transformers are usually connected to the supply system through series fuses instead of circuit breakers. Consequently, no automatic protective relay equipment is required. However, the probability of faults on power transformers is undoubtedly more and hence automatic protection is absolutely necessary. Common transformer faults. As compared with generators, in which many abnormal conditions may arise, power transformers may suffer only from : (i) open circuits (ii) overheating (iii) winding short-circuits e.g. earth-faults, phase-to-phase faults and inter-turn faults. An open circuit in one phase of a 3-phase transformer may cause undesirable heating. In practice, relay protection is not provided against open circuits because this condition is relatively harmless. On the occurrence of such a fault, the transformer can be disconnected manually from the system. Overheating of the transformer is usually caused by sustained overloads or short-circuits and very occasionally by the failure of the cooling system. The relay protection is also not provided against this contingency and thermal accessories are generally used to sound an alarm or control the banks of fans. Winding short-circuits (also called internal faults) on the transformer arise from deterioration of winding insulation due to overheating or mechanical injury. When an internal fault occurs, the transformer must be disconnected quickly from the system because a prolonged arc in the transformer may cause oil fire. Therefore, relay protection is absolutely necessary for internal faults.

2. WORKING

A) **Alternator**

An alternator is defined as a machine or generator which produces AC (Alternating Current) supply and it converts mechanical energy into electrical energy, so it is also called an AC generator or synchronous generator. There are different types of alternators based on applications and design. The Marine type alternator, Automotive type alternator, Diesel-electric locomotive types alternator, Brushless type alternator, and Radio alternators are the types of alternators based on the applications. The Salient Pole type and Cylindrical rotor type are the types of alternators based on the design.

1. Working Principle: The alternator working principle is based on Faraday’s law where motion between a conductor and a magnetic field induces an electrical current.

2. Induction Process: Maximum current induction in an alternator occurs when the conductor’s motion is perpendicular to the magnetic flux lines.

3. Current Alternation: In an alternator, the electrical current reverses direction with each half-turn of the rotor, simulating a complete sine wave during each rotation.

B) **Transformers**

Electrical transformer is a static electrical machine which transforms electrical power from one circuit to another circuit, without changing the frequency. Transformer can increase or decrease the voltage with corresponding decrease or increase in current.

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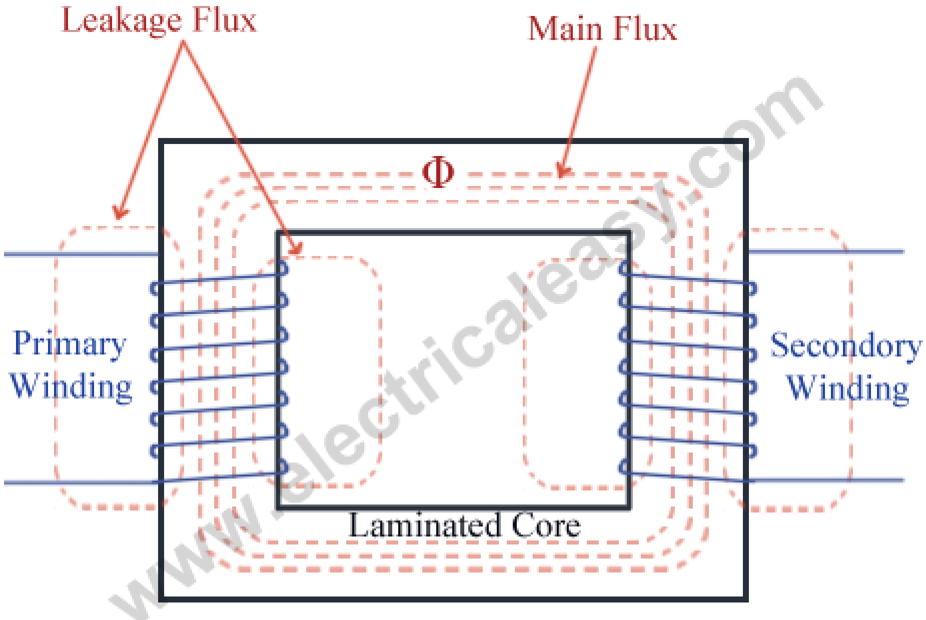

The basic principle behind working of a transformer is the phenomenon of mutual induction between two windings linked by common magnetic flux. The figure at right shows the simplest form of a transformer. Basically a transformer consists of two inductive coils; primary winding and secondary winding. The coils are electrically separated but magnetically linked to each other. When, primary winding is connected to a source of alternating voltage, alternating magnetic flux is produced around the winding. The core provides magnetic path for the flux, to get linked with the secondary winding. Most of the flux gets linked with the secondary winding which is called as 'useful flux' or main 'flux', and the flux which does not get linked with secondary winding is called as 'leakage flux'. As the flux produced is alternating (the direction of it is continuously changing), EMF gets induced in the secondary winding according to Faraday's law of electromagnetic induction. This emf is called 'mutually induced emf', and the frequency of mutually induced emf is same as that of supplied emf. If the secondary winding is closed circuit, then mutually induced current flows through it, and hence the electrical energy is transferred from one circuit (primary) to another circuit (secondary).

3. PROTECTION OF ALTERNATORS

Alternator protection involves safeguarding against faults like stator winding faults, unbalanced loading, and abnormal operating conditions such as motoring, overspeed, and field failure. Key protection schemes include differential protection for stator faults, reverse power relays to prevent motoring, and negative sequence relays for unbalanced loads. Other protections include overcurrent and overspeed protection, and rotor earth fault protection. Electrical protection

Differential protection:

This is the primary method for protecting the stator winding against faults like phase-to-phase or phase-to-earth faults. It works by comparing the currents at the stator's two ends. Under normal conditions, the currents are equal, but a fault within the protected section creates a difference, which trips the relay and isolates the generator.

Reverse power protection:

When the prime mover fails, the alternator can start to "motor" by drawing power from the system. A reverse power relay detects this power flow in the reverse direction and trips the generator to prevent damage from overheating.

Negative sequence protection:

Unbalanced loads can cause a negative sequence current component that rotates in the opposite direction of the rotor. This can lead to overheating of the rotor. Negative sequence or unbalance relays are used to detect this condition and provide protection.

Overcurrent protection:

This is used to protect the alternator from excessive current due to faults, and is also used in conjunction with overspeed protection.

Rotor earth fault protection:

This scheme protects against earth faults in the rotor winding, typically using a DC injection method with a voltage-sensitive relay.

Mechanical and other protection

Overspeed protection:

This is crucial for preventing damage from excessive speed, especially in case of prime mover issues. It is often achieved using a governor, and a differential relay can also be used.

Prime mover failure protection:

This is the mechanical counterpart to reverse power protection. In a hydro-generator set, a mechanical device can be used to disconnect the alternator when the water flow is insufficient. For a diesel engine, the reverse power relay is the primary protection.

Environmental protection:

In dusty environments, filters can be added to the air inlets to prevent particles from entering the alternator. For the most demanding conditions, a totally enclosed machine with a dual-fluid cooling system can be used.

4. PROTECTION OF TRANSFORMERS

Transformer protection is essential to prevent damage from faults and ensure the reliability and safety of electr ical systems.

Importance of Transformer Protection

Transformers are critical components in power systems, and protecting them from faults is vital for maintaining syste m stability and preventing catastrophic failures. Transformer protection schemes are designed to detect abnormal cond itions and mitigate risks associated with internal and external faults.

Types of Transformer Protection

Differential Protection: This method detects internal faults by comparing the current entering and leaving the transfor mer. If there is a discrepancy, it indicates a fault within the transformer.

Overcurrent Protection: This provides backup protection against short circuits and overload conditions. It is commonly used in conjunction with other protection methods.

Buchholz Relay Protection: This device monitors gas accumulation and oil flow in oil-immersed transformers, indicating internal faults. It is essential for detecting incipient faults before they escalat

Temperature Protection: Sensors monitor the winding and oil temperatures to prevent overheating, which can lead to i nsulation failure and transformer damage.

Earth Fault Protection: This detects insulation failures and ground faults within the transformer or connected systems, helping to prevent electrical hazards.

Sudden Pressure Relay Protection: This system senses rapid pressure changes due to internal arcing faults, providing a n additional layer of safety.

Restricted Earth Fault Protection (REF): This offers sensitive internal fault protection by detecting leakage currents wi thin a defined zone, ensuring quick response to faults.

5. ADVANTAGES

A) Alternators

- Fast and selective operation
- High sensitivity to internal faults
- Provides localized protection

B) TRANSFORMERS

- Prevent damage to expensive equipment,
- Ensure system reliability, and enhance safety.
- It detects faults like overloads or short circuits,
- Isolates the affected transformer, and minimizes downtime.

6. CONCLUSION

The conclusion is that protection for alternators and transformers is essential to prevent catastrophic failures, damage to other equipment, and to ensure personnel safety by quickly detecting and isolating faults through a combination of protective relays and schemes like differential protection for internal faults and overcurrent protection for external issues. Proper protection limits repair costs and minimizes downtime, with comprehensive schemes for expensive and critical components and simpler methods for smaller equipment.

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