Chapter 12

Electrical System

12.1 INTRODUCTION

Without having knowledge about electrical equipment. Power generation from the power plant is difficult to understand. Hence it is necessary to have an idea about role of electrical equipment. The purpose of this chapter is to introduce the students to the electrical equipments used in power plant. The main electrical equipments are as follows;

(1) Generator and generator cooling

(2) Transformers and their cooling

(3) Bus bars

(4) Excitors

(5) Reactors

(6) Circuit breakers

(7) Switch board

(8) Control room equipment

12.2 GENERATORS AND MOTORS

In a generator, an e.m.f. is produced by the movement of a coil in a magnetic field. The current produced by the e.m.f. Interacts with the field to produce a mechanical force opposing the movement, and against which the essential movement has to be maintained. The electrical power ei is produced therefore from the mechanical power supplied.

In a motor, we may suppose a conductor or coil to lie in a magnetic field. If current is supplied to the coil; a mechanical force is mani-fested and due to this force the coil will move. Immediately that relative movement takes place between coil and field, however, an e.m.f. is induced, in opposition to the current.

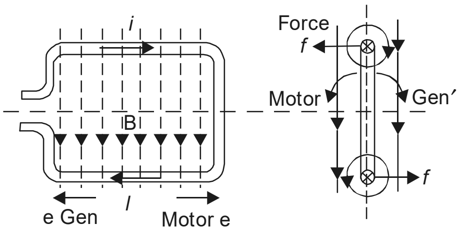


Fig. 12.1

To maintain the current and the associated motor action, it is therefore necessary to apply to the coil, from an external source, a voltage sufficient to overcome the induced e.m.f. Thus the motor requires electrical power to produce a corresponding amount of mechanical power.

6. Leads and Terminals. The connections to the windings are copper rods or bars, insulated wholly or in part, and taken to the bus bars directly in the case of air-cooled transformers, or to the insulator bushings on the tank top in the case of oil-cooled trans-formers. The shape and size of the conductors are of importance in very high voltage systems, not on account of the current-carrying capacity, but because of dielectric stresses, corona, etc., at sharp bends and corners with such voltages.

7. Bushings. Up to voltages of about 33 kV, ordinary porcelain insulators can be used, which do not require special comment. Above this voltage the use of condenser and of oil-filled terminal bushings, or, for certain eases, a combination of the two, has to be considered. Of course, any conductor can be effectively insulated by au provided that it is at a sufficient distance from other con-ducting bodies and sufficiently proportioned to prevent corona phenomena. Such conditions are naturally unobtainable with transformers where the conductor has to be taken through the cover of the containing tank, although common enough with over-head transmission lines.

The oil filled bushing consists of a hollow porcelain cylinder of special shape with a conductor (usually a hollow tube) through its centre. The space between the conductor and the porcelain is filled with oil, the dielectric strength of which is greater than that of air. The dielectric field strength is greatest at the surface of the conductor, and this breaks down at a much lower voltage in air than in oil. Oil is fed into the bushing at the top, where there is a glass cylinder to indicate the oil-level and to act as an expansion chamber for the oil when the bushing temperature rises.

Under the influence of the electric field, foreign substances in the form of dust, moisture or metallic particles, have a tendency to arrange themselves in radial lines, giving rise to paths of low dielectric strength, with consequent danger of breakdown. To prevent such action by unavoidable impurities in the oil, Bakelite tubes are used to surround the conductor concentrically. The effect is to break up radial chains of semi-conducting particles.

Provision must be made in oil-filled bushings for the differing coefficients of linear expansion of porcelain and the metal conductor. The capacitor-type bushing is constructed of thick layers of bakelized paper alternating with thin graded layers of tin-foil.

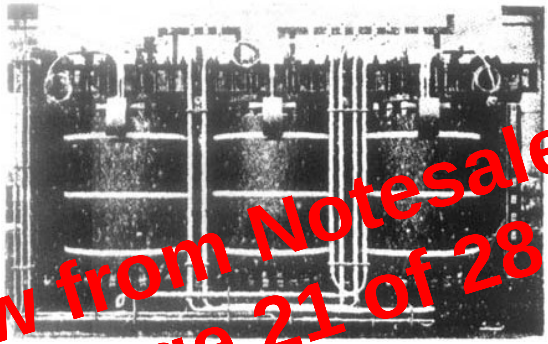
The result is a series of capacitors formed by the conductor and the first tin-foil layer, the first and second tip-foil layers and so on. Their length and the radial separation of their tin-foil plates control the capacitance of the capacitors. Fig. 12.23 illustrates this. If the thickness of bakelized paper separating successive tin-foil layers is kept constant, and the capacitances of the capacitors are kept constant by successively reducing the length of the tin-fail layers proceeding outward, then the voltage across each capacitor will be the same, giving a practically uniform dielectric stress throughout the radial depth of the insulator. By arranging, the dielectric stress to come within the limits of the material used, a hushing can be built to withstand any desired voltage. In Fig. 12.23 the short stepped end is oil-immersed beneath the tank cover, the smooth long end projecting outwards. For use in out door substations, porcelain rain-shed, the annular space between the rain-shed and the bushing proper being filled up with bitumen cover the bushing. The rain-sheds are corrugated circumf6rentially to accord with the estimated electric field distribution and to provide a long leakage path.

higher static head than the water, so that any leakage will be in the direction of oil to water. The system is suitable for application to banks of transformers, but for reliability not more than, say, three tanks should be con-nected in one cooling pump circuit.

Fig. 12.25(*e*) and (*f*) shows diagrammatically the usual methods of cooling employed where separate radiators are necessary. The oil circulation pump in (*e*) is incorporated only if the natural thermal head is insufficient to generate an adequate oil flow.

Until recently all large units employed oil-circulating systems, but considerable advances have been made towards increasing the size of self-cooled units by special radiators. It is possible to build entirely self-cooled units up to 40000 kVA, with the advantage of eliminating breakdown risks due to auxiliary pumping equipment. The addition of an air-blast system to circulate cooling air over the radiators permits the increase of size to about 75000 kVA. Although an auxiliary fan is involved, the transformer is still capable of half- load operation should the air blast fail. A temperature device can be used to bring the fan into action when the oil temperature reaches a desired limit; this improves the overall efficiency at small loads. An arrangement of this type is illustrated in Fig. 12.26.

Tank-less, air-insulated. transformers have been built up to 1500 kVA, but larger sizes require forced air circulation.



Core and windings of ON/OFB 22.5 MVA, 132/33 kV Transformer.

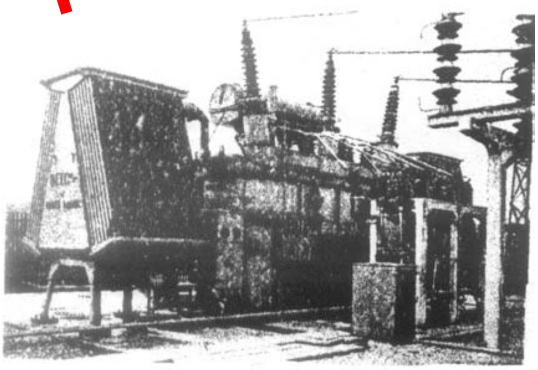


Fig. 12.26. Complete unit OF ON/OFB 22.5 MVA, 132/33 kV Transformer.

12.4.5 INTERNAL COOLING

The heating of the coils depends on their thermal conductivity, which is itself a function of (*a*) the thickness of the winding, and (*b*) the external insulation.

ties of the various circuits. Under normal load conditions or external fault conditions, the sum of the currents entering the bus is equal to those leaving it and no current flows through the relay. If a fault occurs within the protected zone, the currents entering the bus will no longer be equal to those leaving it. The difference of these currents will flow through the relay and cause the opening of the generator, circuit breaker and each of the line circuit breakers.

12.6.2 FAULT BUS PROTECTION

It is possible to design a station so that the faults that develop are mostly earth-faults. This can be achieved by providing earthed metal barrier (known as fault bus, surrounding each conductor throughout its entire length in the bus structure. With this arrangement, every fault that might occur must involve a connection between a conductor and an earthed metal part. By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection.

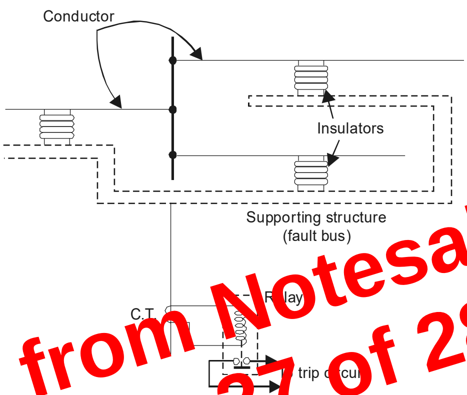


Fig. 12.32

Fig. 12.32 show the schematic arrangement of fault bus protection. The metal supporting structure or fault bus is earthed through a current transformer. A relay is connected across the secondary of this CT. Under normal operating conditions, there is no current flow from fault bus to ground and the relay remains inoperative. A fault involving a connection between a conductor and earthed supporting structure will result in current flow to ground through the fault bus, causing the relay to operate. The operation of relay will trip all breakers connecting equipment to the bus.

THEORETICAL QUESTIONS

1. Write short notes on the following:
   (*a*) Power transformer
   (*b*) Voltage regulation
   (*c*) Transmission of electrical power.

2. Discuss the factors to be considered while deciding the suitability of a transformer.

3. What are the properties of materials used for conductor? Name the materials used for conductors.