كلية المأمون الجامعة

قسم هندسة تقنيات القدرة الكهربائية

المرحلة الرابعة

Protection of Alternators &Transformers

أنظمة النقل والتوزيع

محاضرة رقم (19)

Protection 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*) Over current (*iv*) over speed

(*v*) Over voltage (*vi*) unbalanced loading

(*vii*) stator winding faults

The principal relays and systems used for **Alternator** protection are

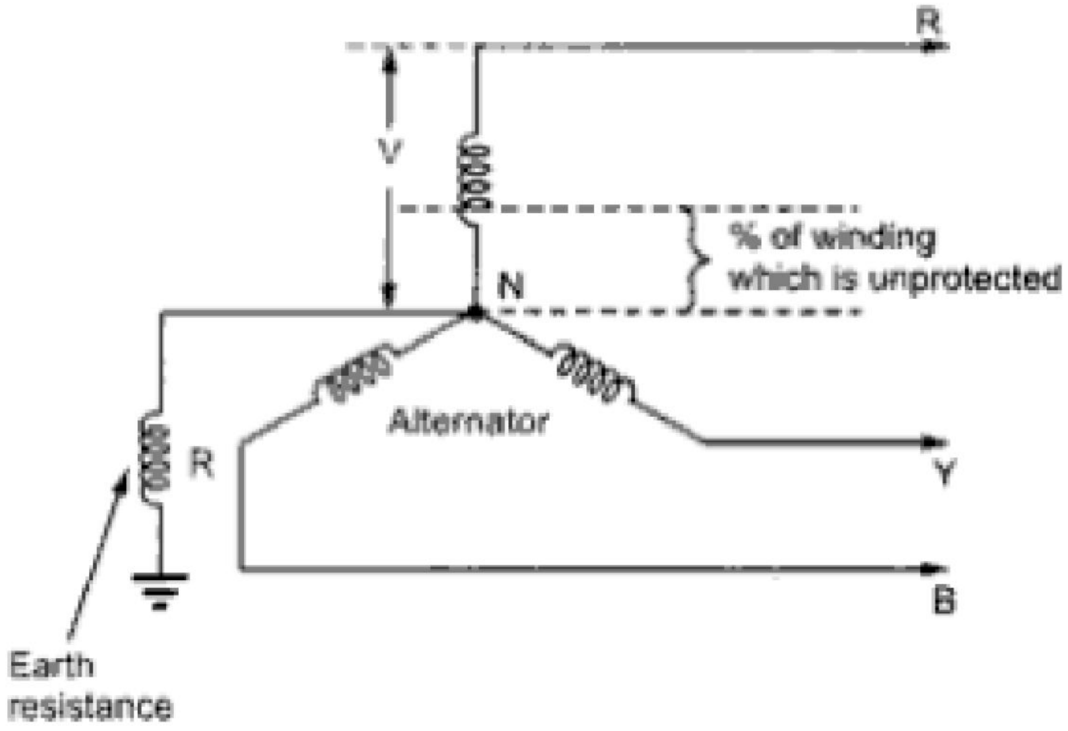
Differential Protection of Alternators

Balanced Earth-Fault Protection

Stator Inter-turn Protection.

Balanced Earth-Fault Protection

the schematic arrangement of a balanced earth-fault protection for a 3-phase alternator. It consists of three line current transformers, one mounted in each phase, having their secondaries connected in parallel with that of a single current transformer in the conductor joining the star point of the alternator to earth. A relay is connected across the transformers secondaries. The protection against earth faults is limited to the region between the neutral and the line current transformers.



Example 22.2. *A star-connected, 3-phase, 10 MVA, 6·6 kV alternator is protected by Merz-Price circulating-current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7·5 Ω. If the minimum operating current for the relay is 0·5 A, calculate the percentage of each phase of the stator winding which is unprotected against earth-faults when the machine is operating at normal voltage.*

Solution. Let x % of the winding be unprotected.

Earthing resistance, $r = 7{\cdot}5\ \Omega$

Voltage per phase, $V_{ph} = 6{\cdot}6 \times 10^3/\sqrt{3} = 3810$ V

Minimum fault current which will operate the relay

$$= \frac{1000}{5} \times 0{\cdot}5 = 100\text{ A}$$

E.M.F. induced in x% winding $= V_{ph} \times (x/100) = 3810 \times (x/100) = 38{\cdot}1\,x$ volts

Earth fault current which x% winding will cause

$$= \frac{38{\cdot}1\,x}{r} = \frac{38{\cdot}1\,x}{7{\cdot}5} \text{ amperes}$$

This current must be equal to 100 A.

$$\therefore \qquad 100 = \frac{38{\cdot}1\,x}{7{\cdot}5}$$

Unprotected winding, $x = \dfrac{100 \times 7{\cdot}5}{38{\cdot}1} = \mathbf{19{\cdot}69\%}$

Hence 19·69% of alternator winding is left unprotected.

Protection of Transformers

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.

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.*

Transformer Relays

The principal relays and systems used for transformer protection are :

(*i*) *Buchholz devices* providing protection against all kinds of incipient faults *i.e.* slow-developing faults such as insulation failure of windings, core heating, fall of oil level due to leaky joints etc.

(*ii*) *Earth-fault relays* providing protection against earth-faults only.

(*iii*) *Overcurrent relays* providing protection mainly against phase-to-phase faults and overloading.

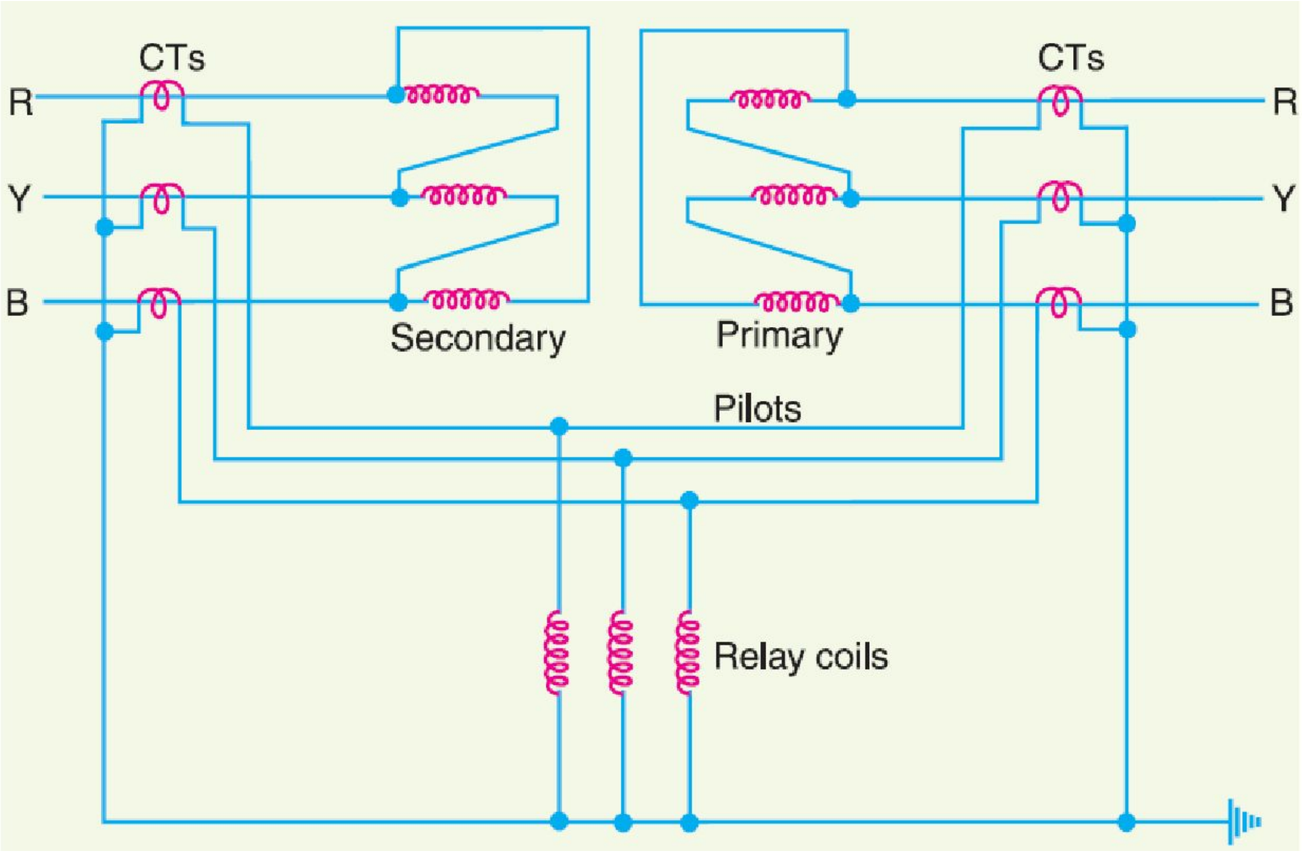
(*iv*) *Differential system* (or circulating-current system) providing protection against both earth and phase faults.

Differential system (or circulating-current system)

Merz-Price circulating -current principle is commonly used for the protection of power transformers against earth and phase faults. The system as applied to transformers is fundamentally the same as that for generators but with certain complicating features not encountered in the generator application.

S. No.	Power transformer connections		Current transformer connections	
	Primary	Secondary	Primary	Secondary
1	Star with neutral earthed	Delta	Delta	Star
2	Delta	Delta	Star	Star
3	Star	Star with neutral earthed	Delta	Delta
4	Delta	Star with neutral earthed	Star	Delta

Merz-Price circulating-current scheme for the protection of a 3- phase delta/delta power transformer against phase-to ground and phase-to-phase faults. Note that *CT*s on the two sides of the transformer are connected in star. This compensates for the phase difference between the power transformer primary and secondary. The *CT*s on the two sides are connected by pilot wires and one relay is used for each pair of *CT*s.



Example 22.5. *A 3-phase transformer of 220/11,000 line volts is connected in star/delta. The protective transformers on 220 V side have a current ratio of 600/5. What should be the CT ratio on 11,000 V side ?*

Solution. For star/delta power transformers, *CT*s will be connected in delta on 220 V side (*i.e.* star side of power transformer) and in star on 11,000 V side (*i.e.* delta side of power transformer) as shown in Fig. 22.16.

Suppose that line current on 220 V side is 600 A.

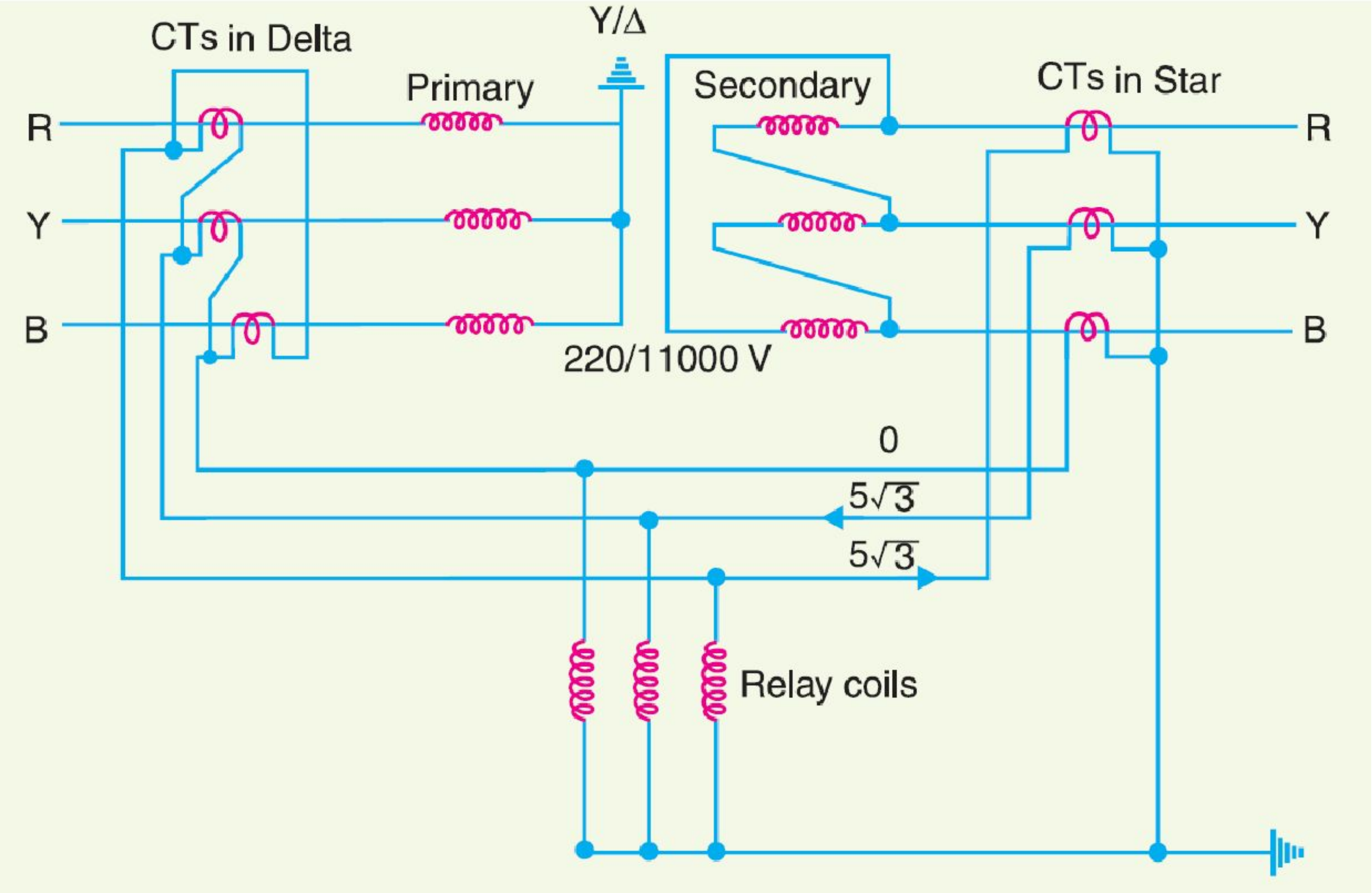
$\therefore$ Phase current of delta connected *CT*s on 220V side

$$= 5 \text{ A}$$

Line current of delta connected *CT*s on 220 V side

$$= 5 \times \sqrt{3} = 5\sqrt{3} \text{ A}$$

This current (*i.e.* $5\sqrt{3}$) will flow through the pilot wires. Obviously, this will be the current which flows through the secondary of *CT*s on the 11,000 V side.


Y/Δ
CTs in Delta
Primary
Secondary
CTs in Star
R
Y
B
R
Y
B
220/11000 V
0
5√3
5√3
Relay coils

$\therefore$ Phase current of star connected *CT*s on 11,000 V side = $5\sqrt{3}$ A

If *I* is the line current on 11,000 V side, then,

$$\text{Primary apparent power} = \text{Secondary apparent power}$$

$$\sqrt{3} \times 220 \times 600 = \sqrt{3} \times 11{,}000 \times I$$

$$I = \frac{\sqrt{3} \times 220 \times 600}{\sqrt{3} \times 11000} = 12 \text{ A}$$

$\therefore$ Turn-ratio of *CT*s on 11000 V side

$$= 12 : 5\sqrt{3} = \mathbf{1{\cdot}385 : 1}$$

Example 22.6. *A 3-phase transformer having line-voltage ratio of 0·4 kV/11kV is connected in star-delta and protective transformers on the 400 V side have a current ratio of 500/5. What must be the ratio of the protective transformers on the 11 kV side ?*