9

SYSTEM NEUTRAL GROUNDING

9.1 INTRODUCTION

A ***system neutral ground*** is a connection to ground from the neutral point or points of a system or rotating machine or transformer. The neutral grounding is an important aspect of power system design because the performance of the system in terms of short circuits, stability, protection, etc., is greatly affected by the condition of neutral. A three-phase system can be operated in two possible ways:

1. With ungrounded neutral
2. With grounded neutral

9.2 UNGROUNDED NEUTRAL SYSTEM

In an ungrounded neutral system, the neutral is not connected to ground. In other words, the neutral is isolated from the ground. Therefore, this system is also known as ***isolated neutral system*** or ***free neutral system***. It is shown in Fig. 9.1.

The line conductors have distributed capacitances between one another and to ground. The former are delta connected while the latter are star connected as shown in Fig. 9.2. The delta connected capacitances current becomes three times the normal per phase charging current under balanced conditions.

9.3 ARCING GROUNDS

The insulation of all equipment connected to the lines is subjected to the high voltage. If it exists for a very short duration, the insulation may be able to withstand it, otherwise it may be damaged. For operating the protective devices, it is necessary that the current should be sufficient in magnitude. However, in case of a single line-to-ground fault on an isolated neutral system, the resultant capacitive current is usually large enough to operate the protective device. Further, a current of over 4 or 5 A flowing through the fault may give rise to an arc in the ionized part of the fault. With the formation of the arc, the voltage across it becomes zero and, therefore, the arc is extinguished. The potential of the faulty conductor is restored and the formation of second arc takes place. The phenomenon of intermittent arcing is called the ***arcing ground***. The successive extinction and reignition of the charging current flowing in the arc may increase the potential of the other two healthy conductors appreciably due to setting up of high-frequency oscillations. These high-frequency oscillations are superimposed on the system and produce surge voltages as high as six times the normal value. The overvoltages in healthy conductors may damage the insulation at some other point of the system.

9.4 ADVANTAGES OF NEUTRAL GROUNDING

Because of the problems associated with ungrounded neutral systems, the neutrals are grounded in most of the modern high-voltage systems. Some of the advantages of neutral grounding are as follows:

1. Voltages of phases are limited to the line-to-ground voltages.
2. Surge voltages due to arcing grounds are eliminated.
3. The overvoltages due to lightning are discharged to ground.
4. The induced static charges do not produce any disturbance since they are conducted to ground.
5. The ground relays can be used to protect against the ground faults.
6. It provides greater safety to personnel and equipment.
7. It provides improved service reliability.
8. Operating and maintenance expenditure is reduced.

9.5 METHODS OF NEUTRAL GROUNDING

The methods commonly used for grounding the system neutral are:

1. Solid grounding (or effective grounding)
2. Resistance grounding
3. Reactance grounding
4. Peterson-coil-grounding (or resonant grounding).

The selection of the type of grounding depends on the size of the unit, system voltage and protection scheme to be used.

9.6 SOLID GROUNDING

The term effectively grounded is now used instead of the old term "solidly grounded". A power system is said to be effectively grounded when the neutral of a generator, power transformer, or grounding transformer are directly connected to ground through a conductor of negligible resistance and negligible reactance as shown in Fig. 9.6. A system or a portion of a system is defined to be effectively grounded when $R_0 \leq X_1$ and $X_0 \leq 3X_1$, such relationships exists at any point in the system for any condition of operation and for any amount of generator capacity.

Here,

R_0 = zero-sequence resistance

X_0 = zero-sequence reactance

X_1 = positive-sequence reactance.

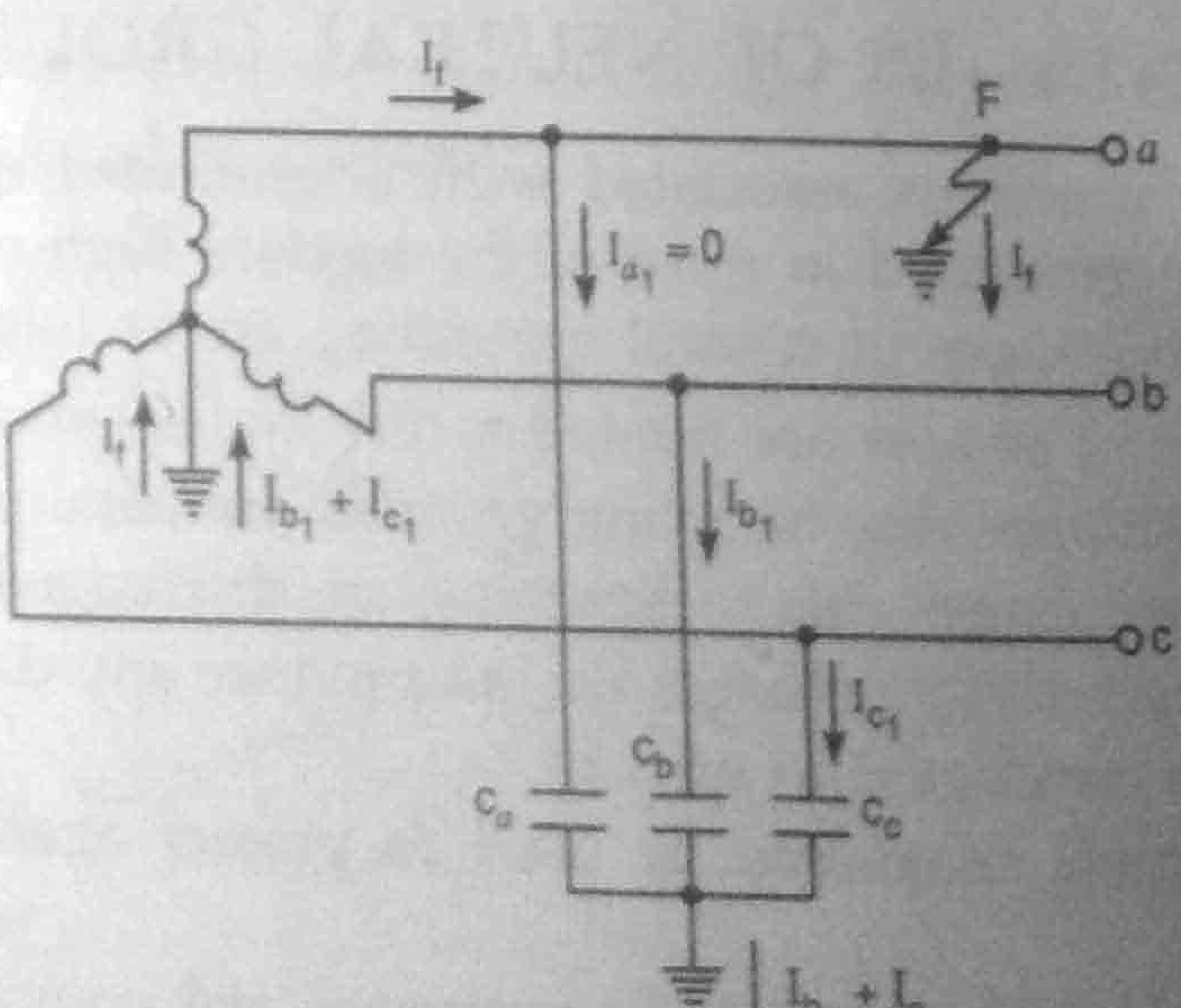

Fig. 9.6 Solidly grounded system

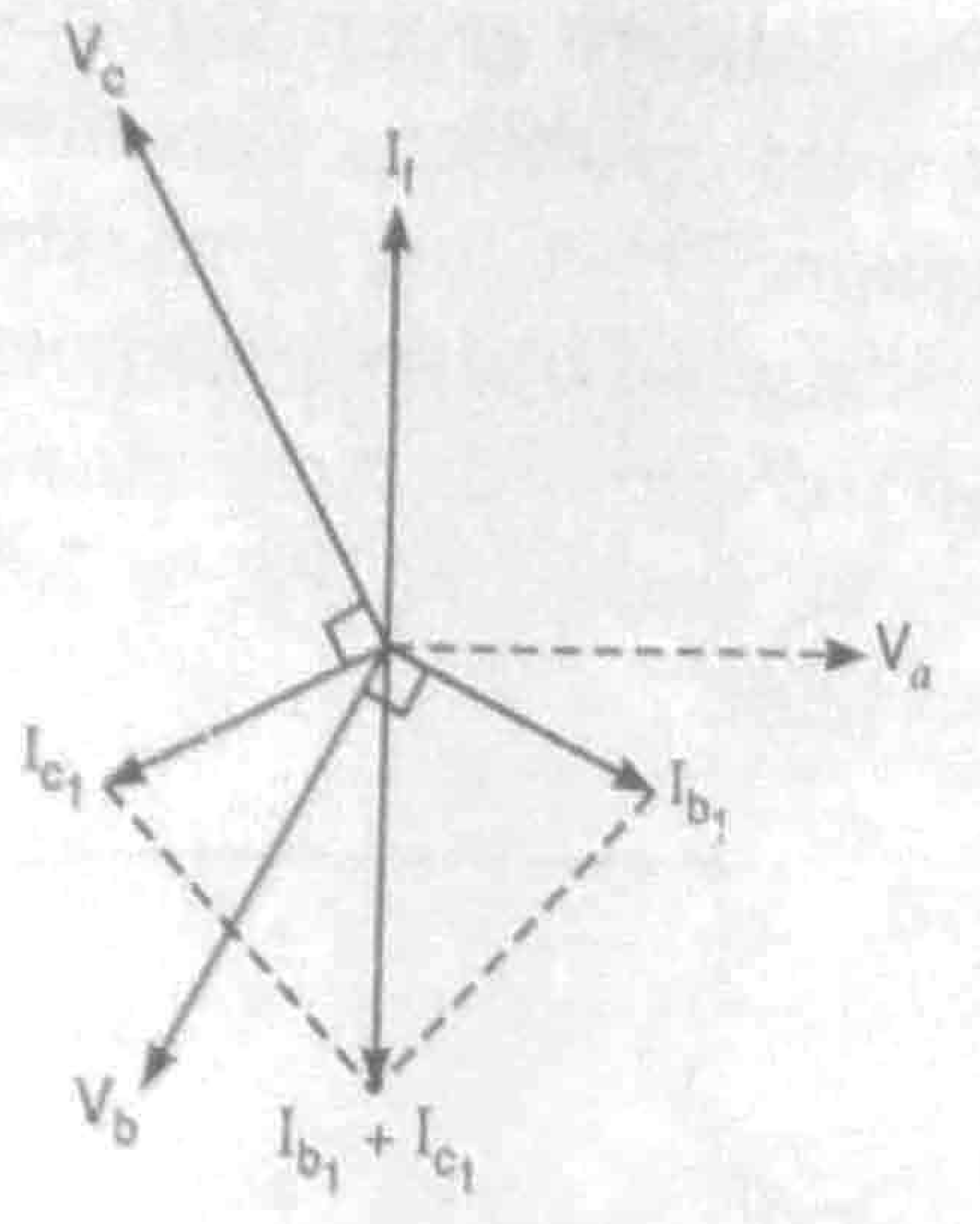

Fig 9.7 Phasor diagram of a solidly grounded system.

Consider a line-to-ground fault in line a at point F as shown in Fig. 9.6. As a result of this fault the line-to-ground voltage of phase a becomes zero. However, the remaining two phases b and c will still have the same voltages as before as shown in Fig. 9.7.

It should be noted that in this system, in addition to charging currents, the power source also feeds the fault current If. As the generator or transformer have their own reactances in series with the neutral circuit, solid grounding does not make a zero-impedance circuit. If the impedance of the generator is too low, solid grounding of the generator without any external impedance may cause the single line-to-ground fault current from the generator to exceed the maximum three-phase fault current which the generator can deliver, and this may exceed the short-circuit current for which its windings are braced. If the reactance of the generator or transformer is very large, then also the purpose of grounding is defeated. For solidly grounded systems, it is necessary that the ground fault current should not exceed 80% of the 3-phase fault current to prevent the production of surge voltages.

9.7 RESISTANCE GROUNDING

In a resistance-grounded system, the system neutral is connected to ground through one or more resistors as shown in Fig. 9.8. Resistance grounding limits the ground fault currents. A system that is properly grounded by resistance is not subject to dangerous transient overvoltages. Resistance grounding reduces the arcing ground hazards and permits ground-fault protection.

The value of resistance to be used in the neutral to be grounded should neither be very low nor very high. A very low resistance, makes the system similar to the solidity grounded system. If the grounding resistance is high, the system conditions becomes similar to an isolated (ungrounded) neutral system. The value of resistance is chosen such that the ground-fault current is limited but still sufficient ground current flows to permit the operation of ground fault protection. In general, the ground-fault current may be limited to 5% to 20% of that which would occur with a three-phase fault.

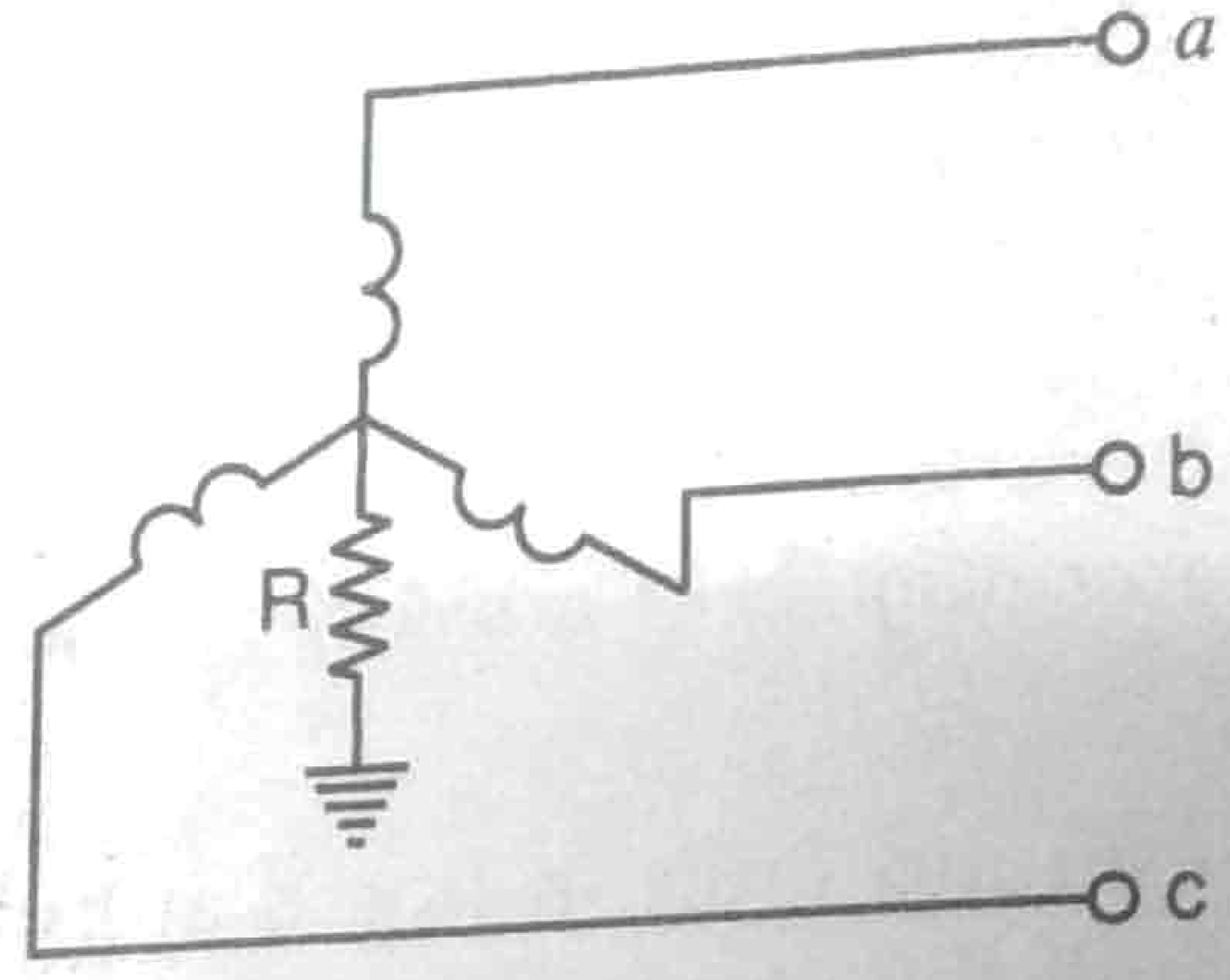

Fig. 9.8 Resistance grounding

9.8 REACTANCE GROUNDING

In this system a reactance is inserted between the neutral and ground to limit the fault current as shown in Fig. 9.9. In order to minimize transient overvoltages, the ground-fault current of a reactance grounded system should not be less than 25% of the 3-phase fault current. This is considerably more than the minimum current desirable in resistance-grounded systems.

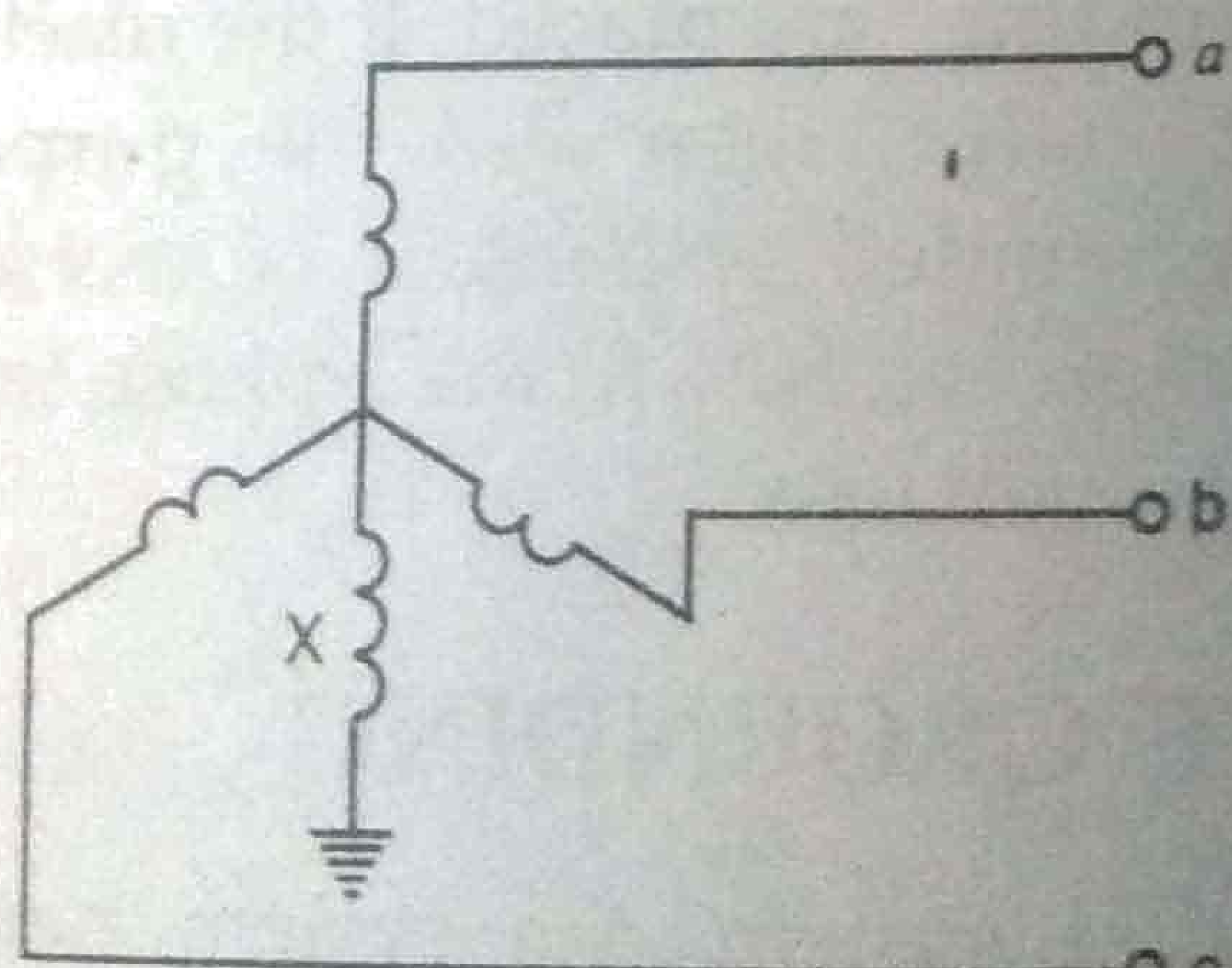

Fig. 9.9. Reactance grounding.