Sequence Impedances of a Synchronous Generator

Theory:

The sequence impedances of an alternator have differing values. This is because of the difference in the effect of the armature m.m.f on the DC field m.m.f for different sequences. They may be defined as:

Positive Sequence Impedance

It is the ratio of the fundamental component of armature voltage, due to the fundamental positive sequence component of armature current, to this component of armature current at rated frequency. This is the usual impedance (either synchronous or transient or subtransient) of alternator.

Negative Sequence Impedance

It is the ratio of fundamental component of armature voltage, due to the fundamental negative sequence component of armature current, to this component of armature current at rated frequency

Zero Sequence Impedance

It is the ratio of fundamental component of armature voltage, due to the fundamental zero sequence component of armature current, to this component of armature current at rated frequency.

Procedure:

Positive Sequence Impedance (Xd" and Xq")

1. FIG.1. Apply a single-phase voltage to two phases (of the stator) in series of a stationary star-connected alternator. Adjust the rotor position so that the current due to the induced voltage in the short-circuited field winding is maximum. Neglecting the resistance , Xd" will be :

$$Xd'' = V/2I''$$

where I" is the current flowing through the two phase of the alternator with an applied voltage V.

2. Turn the rotor through half pole pitch, q-axis will coincide with crest of the armature m.m.f and the reactance offered by the armature would now be Xq".
3. For any rotor position, apply single-phase voltage across two windings in series (say, phases A and B) and obtain the reactance V/2I". For the same rotor position, repeat the test for phase B and C and then C and A in series. X1,X2 and X3 are he reactances obtained (X1 being maximum).Then,

$$Xd'' = K-m$$
$$Xq''= K+m$$

where

$$K= (X1+X2+X3)/3$$

$$m = [\{(X1-K)^2 + (X2-X3)^2\}/3]^{1/2}$$

Negative Sequence Impedance (X2)

One possible method of measuring X2 is to run he machine at rated speed with its field winding closed and to impress a balanced 3-phase voltage on the armature terminals. Adjust the phase sequence of the voltage so that the current due to this voltage in 3-phase armature windings sets up a rotating field in a direction opposite to the direction of rotation of the machine. The negative sequence impedance is then the ratio of impressed voltage and current per phase. A wattmeter connected in the circuit will give the negative sequence resistance power loss and thus the value of r2. The value of X2 can then be calculated.

FIG.2 gives the connection diagram for another method. Two phase A and B of the star-connected alternator are short-circuited and voltage V is measured between C and the junction terminals A and B. The machine is driven at rated speed. The negative sequence impedance is then

$$Z2 = V/(\sqrt{3}I)$$

The value of X2 can be obtained with the help of the wattmeter reading P, as

$$X2 = PZ2/(VI)$$

Short-circuit current is kept low so that the heating of he field system is within the thermal capability of the machine.

Zero Sequence Impedance

Connect all the three phases of the armature winding in series and apply a reduced voltage as shown in FIG.3. Drive the machine at rated speed with the field winding short-circuited. Then,

X0=Z0= V/(3I) per phase.

Where I is the current through each winding.

Report:

Positive Sequence Impedance

$$X1 = V/2I_1'' =$$
$$X2 = V/2I_2'' =$$
$$X3 = V/2I_3'' =$$
$$K = (1/3)(X1+X2+X3) =$$
$$m = [\{(X1-K)^2 + (X2-X3)^2\}/2]^{1/2}$$
$$Xd'' = K-m$$
$$Xq'' = K+m$$

Negative Sequence Impedance

V=

I=

P=

$$Z2 = V/(\sqrt{3}I) =$$
$$X2 = PZ2/(VI) =$$

Zero Sequence Impedance

V=
I=
X0=Z0= V/(3I)=

Result:

Xd" =
Xq" =
X2=
X0=

FIG.1 Positive Sequence Impedance

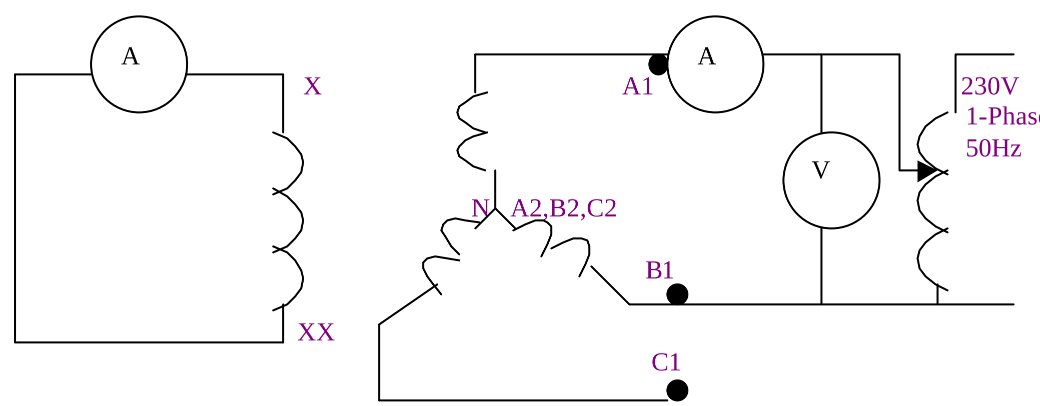

FIG.2 Negative Sequence Impedance

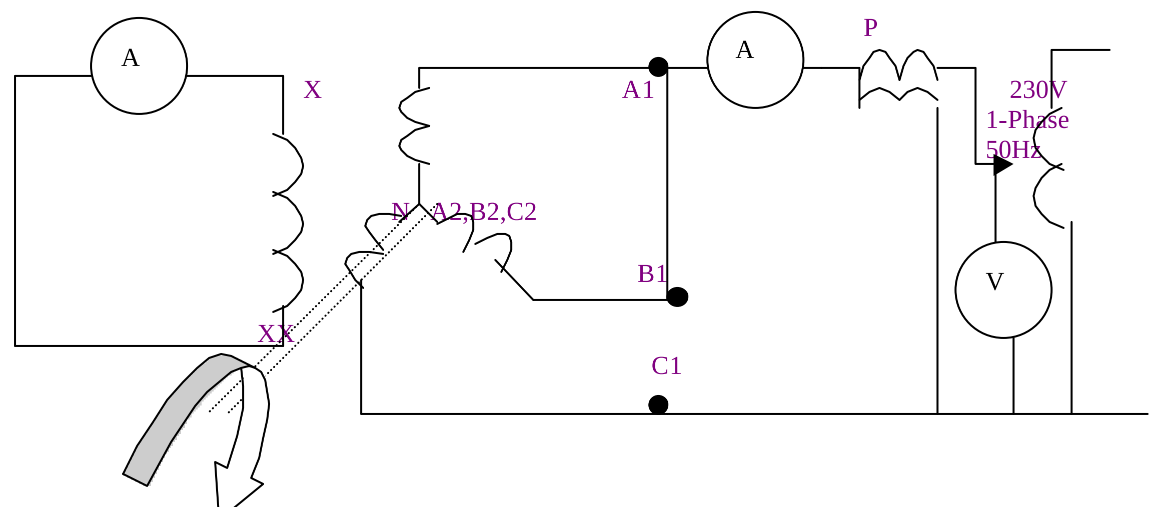

FIG.3 Zero Sequence Impedance