

### Equivalent Circuit Of An Alternator

From the previous discussion it is clear that in all there are three important parameters of armature winding namely armature resistance  $R_a$ , leakage reactance  $X_L$  and armature reaction reactance  $X_{ar}$ . If  $E_{ph}$  is induced e.m.f. per phase on no load condition then on load it changes to  $E'$  due to armature reaction as shown in the equivalent circuit. As current flows through the armature, there are two voltage drops across  $R_a$  and  $X_L$  as  $I_a R_a$  and respectively. Hence finally terminal voltage  $V_t$  is less than  $E'$  by the amount equal to the drops across  $R_a$  and  $X_L$ .

In practice, the leakage reactance  $X_L$  and the armature reaction reactance  $X_{ar}$  are combined to get synchronous reactance  $X_s$ .

Hence the equivalent circuit of an alternator gets modified as shown in the Figure 1.18.

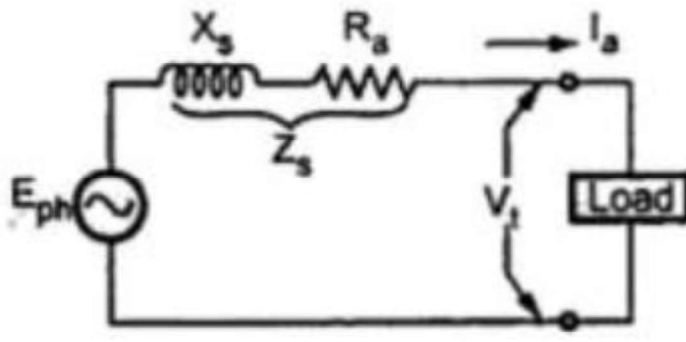


Figure 1.18 Equivalent Circuit

Thus in the equivalent circuit shown,

$E_{ph}$  = induced e.m.f. per phase on no load  $V_{tph}$  =

terminal voltage per phase on load  $I_{aph}$  =

armature resistance per phase

$Z_s$  = synchronous impedance per phase

$$\bar{E}_{ph} = \bar{V}_{tph} + \bar{I}_a \bar{Z}_s \dots \text{(Phasor sum)}$$

### Voltage Equation of an Alternator

In a d.c. generators, we have seen that due to the armature resistance drop and brush drop it is not possible to have all the induced e.m.f. available across the load. The voltage available to the load is called terminal voltage. The concept is same in case of alternators. The entire induced e.m.f. can not be made available to the load due to the various internal voltage drops. So the voltage available to the load is called terminal voltage denoted as  $V_t$ . In case of three phase alternators as all the phases are identical, the equations and the phasor diagrams are expressed on per phase basis. So if  $E_{ph}$  is the induced e.m.f. per phase in the alternator, there are following voltage drops occur in an alternator.

- i) The drop across armature resistance  $I_a R_a$  both  $I_a$  and  $R_a$  are per phase values.
- ii) The drop across synchronous reactance  $I_a X_s$ , both  $I_a$  and  $X_s$  are per phase values.
- iii) After supplying these drops, the remaining voltage of  $E_{ph}$  is available as the

terminal voltage  $V_{ph}$ .

Note : Now drop  $I_a R_a$  is always in phase with  $I_a$  due to a resistive drop while current  $I_a$  lags by  $90^\circ$  with respect to drop  $I_a X_s$  as it is a drop across purely inductive reactance.

Hence all these quantities can not be added or subtracted algebraically but must be added or subtracted vectorially considering their individual phases. But we can write a voltage equation in its phasor form as

$$\vec{E}_{ph} = \vec{V}_{ph} + \vec{I_a R_a} + \vec{I_a X_s}$$

This is called voltage equation of an alternator.

From this equation, we can draw the phasor diagram for various load power factor conditions and establish the relationship between  $E_{ph}$  and  $V_{ph}$ , in terms of armature current i.e. load current and the power factor  $\cos(\Phi)$ .

### Voltage Regulation of an Alternator

Under the load condition, the terminal voltage of alternator is less than the induced e.m.f.  $E_{ph}$ . So if load is disconnected,  $V_{ph}$  will change from  $V_{ph}$  to  $E_{ph}$ , if flux and speed is maintained constant. This is because when load is disconnected,  $I_a$  is zero hence there are no voltage drops and no armature flux to cause armature reaction. This change in the terminal voltage is significant in defining the voltage regulation.

**Note :** The voltage regulation of an alternator is defined as the change in its terminal voltage when full load is removed, keeping field excitation and speed constant, divided by the rated terminal voltage.,

So if  $V_{ph}$  = Rated terminal voltage  $E_{ph}$  =

No load induced e.m.f.

the voltage regulation is defined as,

$$\% \text{ Regulation} = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

### KVA Rating of an Alternator

The alternators are designed to supply a specific voltage to the various loads. This voltage is called its rated terminal voltage denoted as  $V_L$ . The power drawn by the load depends on its power factor. Hence instead of specifying rating of an alternator in watts, it is specified in terms of the maximum apparent power which it can supply to the load. In three phase circuits, the apparent power is  $\sqrt{3} V_L I_L$ , measured in VA (volt amperes). This is generally expressed in kilo volt amperes and is called kVA rating of an alternator where  $I_L$  is the rated full load current which alternator can supply. So for a given rated voltage and kVA rating of an alternator, its full load rated current can be decided.

Consider 60 kVA, 11 kV three phase alternator

$$\text{kVA} = \sqrt{3} V_L I_L \times 10^{-3}$$