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.

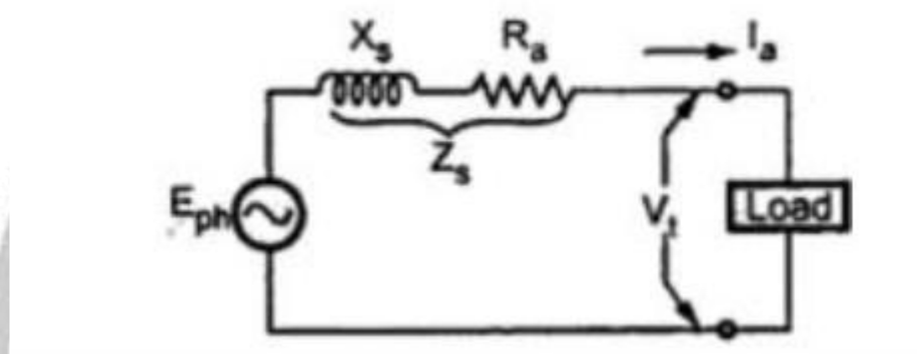

Figure 1.18 Equivalent Circuit

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

$$\overline{E}_{ph} = \overline{V}_{tph} + \overline{I_a Z_s} \; \dots \text{(Phasor sum)}$$

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. 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_o 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 from as

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

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(Φ).

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

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