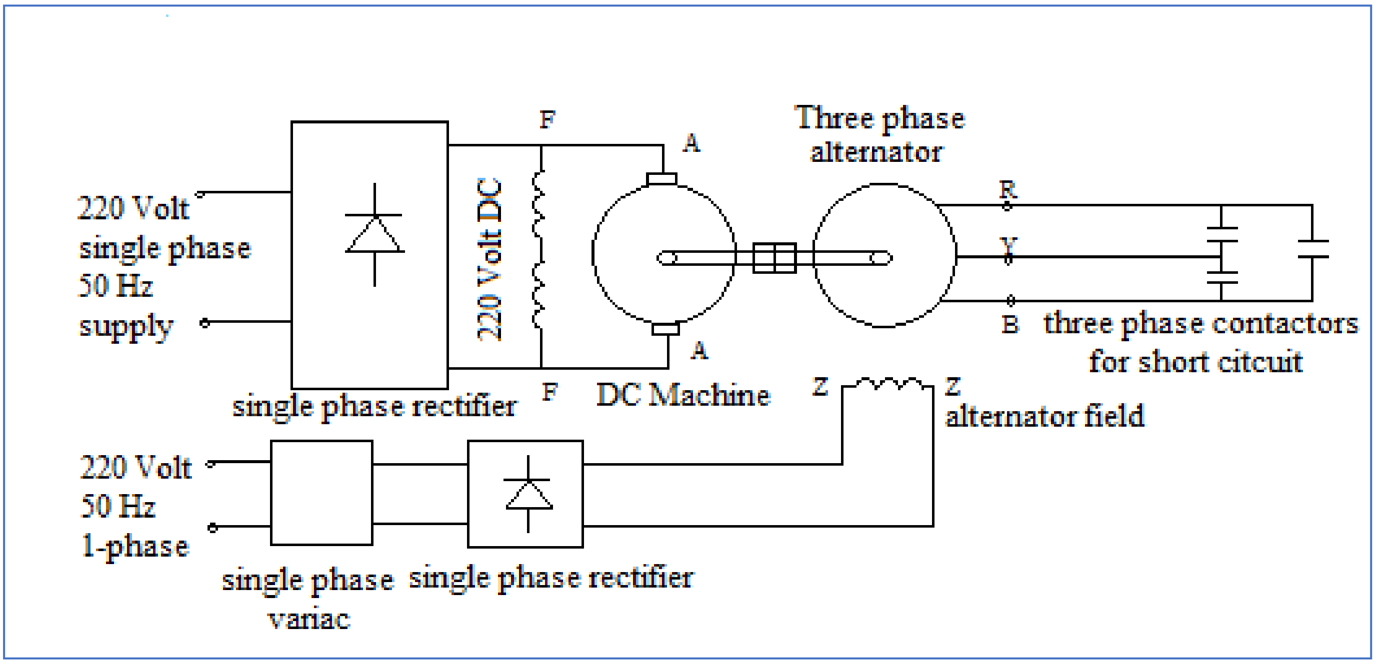
SHORT CIRCUIT TEST AND COMPUTATION OF PARAMETERS OF AN ALTERNATOR

Aim- To find out d-axis subtransient reactance, transient reactance and synchronous reactance (X_d'', X_d', X_d respectively) along with d-axis subtransient short circuit time constant (T_d'') and transient short circuit time constant (T_d') of an alternator following a three phase bolted short circuit at its terminals.

Circuit Diagram-



Theory- The subtransient reactance (X_d''), transient reactance (X_d'), synchronous reactance (X_d), subtransient short-circuit time constant (T_d'') and transient short-circuit time constant (T_d') are used to describe the machine behavior on sudden short circuit. This calculation can be done in accordance with equation (1) for the ac rms components of current following a three-phase short circuit from no load when neglecting armature-circuit resistance and assuming constant exciter voltage and absence of decaying dc component.

$I(t)=(E/X_d)+(E/X_d'-E/X_d).e^{(-t/Td')}+(E/X_d''-E/X_d').e^{(-t/Td'')}$,Where E is the ac rms voltage before short circuit (1)
t is time, in seconds, measured from the instant of short circuit; I(t) is ac rms short circuit current

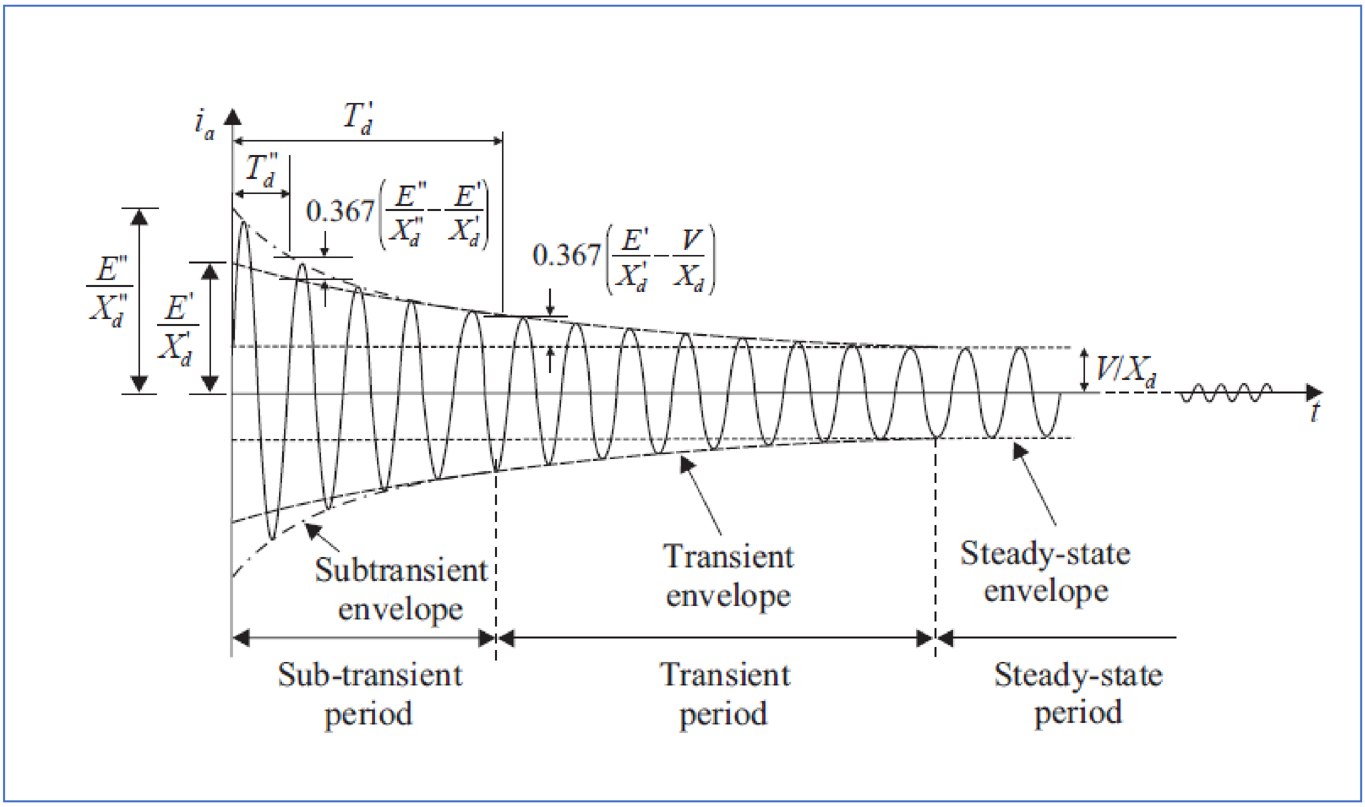


Fig-1: Waveform of current for phase-a

Procedure-

(i)Run the machine at the rated speed with its armature terminals open circuited and field current maintained to keep alternator terminal voltage (E) around (30-40)% of rated terminal voltage. This is done to avoid the effect of core saturation followed by terminal short circuit. Note E.

(ii)Now apply a three phase short circuit at the machine terminals keeping field excitation constant and save the current waveforms for all three phases using oscilloscope (The waveform should start few cycles before short circuit and continue for few more cycles during the short-circuit till currents reach steady state values)

Calculation-

(i)Note the voltage to current conversion factors of the probes. For each phase plot the currents in MATLAB with units in Ampere or per unit and on each plot determine the ***envelopes of short circuit alternating currents***. Draw the DC offset present in the envelopes by taking mean of upper and lower envelopes. Subtract DC offset from the upper envelope and henceforth for all discussions related to current, use these upper envelope values only and not the instantaneous current values anymore. The current envelopes contain three parts, viz, initial fast decaying subtransient followed by linearly decaying transient and finally sustained steady state. Time zero corresponds to the instant of application of short circuit fault.

(ii)Sample the three upper envelopes and enter the values in MATLAB to get the samples for average envelope curve. Get the average envelope curve in a semilogarithmic plot as curve-B of figure-2. Line C corresponds to the transient current (plus the steady state current) and it is obtained by joining the points of curve B immediately after decaying of the initial non-linear subtransient part. This line is extended back to zero time to get the value of initial transient current (after subtracting the steady state current value).

(iii)The values of the difference between the ordinates of curve B and the transient component (line C) are plotted as curve A (on the same sheet). The result is expected to be nearly a straight line on the semilogarithmic plot. Extending the straight line (line D) drawn to fit these points back to zero time gives the initial value of the subtransient component of the short-circuit current (plus the steady state current value). Preference in locating line D should be given to the first few points, corresponding to the first few cycles after application of the short circuit, as they are normally the points that can be determined most accurately.

(iv)The sum of the initial subtransient component, the initial transient component, and the sustained component gives the corresponding value of I''.

Now, d-axis Subtransient Reactance, **Xd"= (E/ I")** (2)

(v)Similarly add up the initial transient component and the sustained component to get the value of I'.

Now, d-axis Transient Reactance, **Xd'= (E/ I')** (3)

(vi)Similarly d-axis Synchronous Reactance, **Xd= (E/I)**, where I is the sustained/ steady state current. (4)

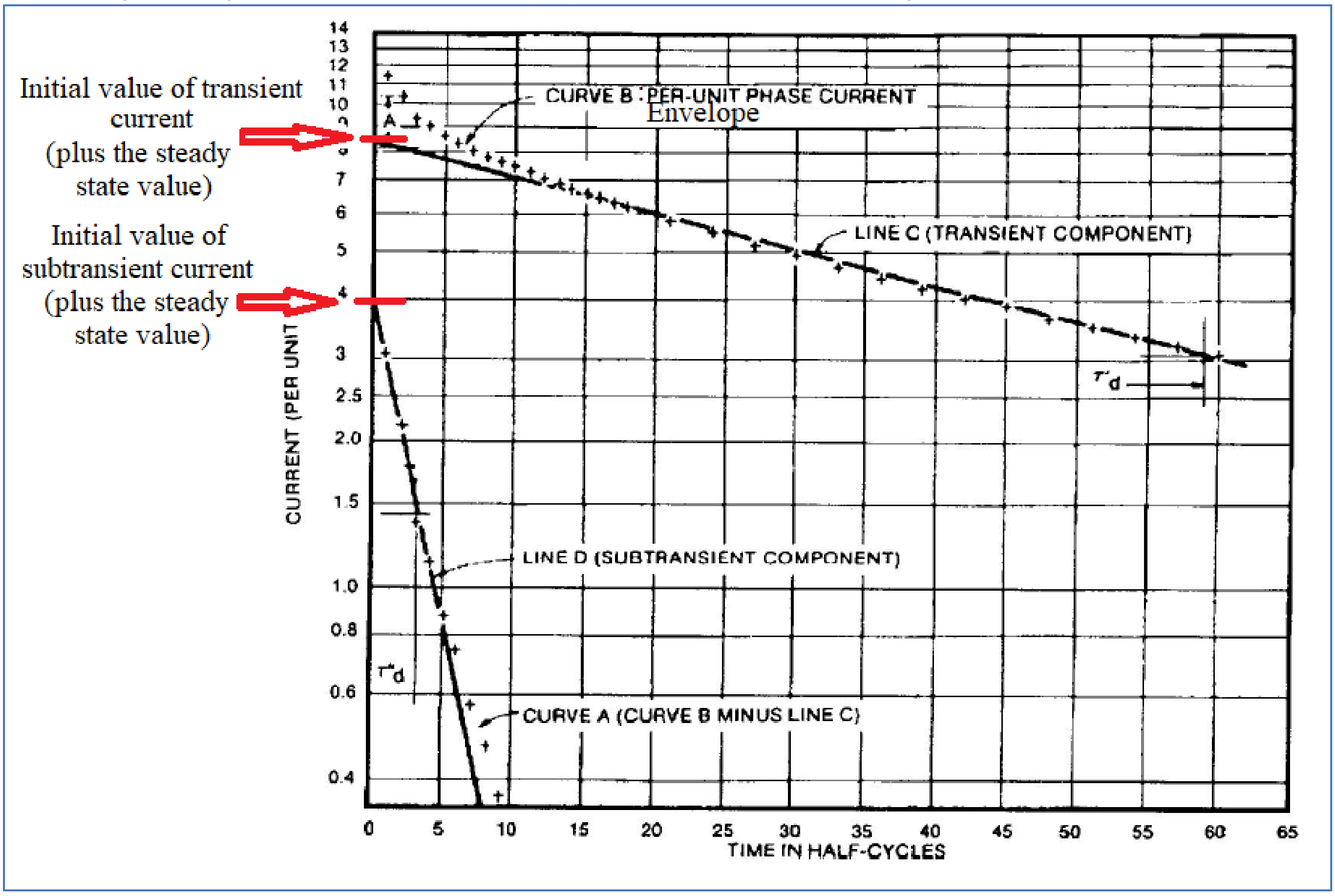


Fig-2: Computation of short circuit parameters

(vii)The direct-axis transient short-circuit time constant (**T_d'**) is the time, in seconds, required for the transient alternating component of the short-circuit current (line C) to decrease to 1/*e*, or 0.368, times its initial value.
(viii)The direct-axis subtransient short-circuit time constant (**T_d"**) is the time, in seconds, required for the subtransient alternating component of the short-circuit current (line D) to decrease to 1/*e*, or 0.368, times its initial value.
The determination of direct-axis subtransient and transient short-circuit time constant is also shown in Figure-2.

Report-
(1) Plot the three phase fault current waveforms using MATLAB reading the sample values from the corresponding .csv files taken from oscilloscope.
(2) Plot the average upper envelope of short circuit current in semilogarithmic scale using MATLAB or otherwise and draw the lines C and D.
(2) Compute the respective d-axis reactances and compare their values.
(3) Compute and compare the required short circuit time constants.

Questions-
1. Differentiate between salient pole and cylindrical rotor alternators in terms of structural details and application areas.
2. What are the d and q axis reactances in a salient pole alternator and which one is greater for such a machine?
3. What is the difference in waveforms upon application of short circuit at a generator terminal and at the terminal of an R-L circuit connected to a sinusoidal supply?
4. Draw the equivalent circuits of a synchronous generator during subtransient, transient, and steady state, after a terminal fault.
5. Where do you need Xd'', Xd', Xd values?