Synchronous machines:

The machines generating alternating emf from the mechanical input are called alternators or synchronous generators. They are also known as AC generators. All modern power stations consist of large capacity, three phase alternators connected in parallel to generate electrical power.

Principle of operation - Synchronous generators: AC generator operates on the same fundamental principle of electromagnetic induction as DC generators. It consists of an armature winding and a magnetic field. In the case of AC generators the armature acts as stationary and the field system is rotating. Here the armature windings are mounted on a stationary element called stator and field windings on a rotating element called rotor.

Types of rotor:

1. Salient pole type
2. Smooth cylindrical type

Difference b/w salient pole and cylindrical type Rotor:

Salient pole	**Smooth cylindrical**
1. Poles are projecting out from the surface.	Unslotted portion of the cylinder acts as poles, hence poles are non projecting.
2. Air gap is non-uniform	Air gap is uniform.
3. Diameter is large and axial length is small	Small diameter and large axial length.
4.Mechanically weak	Mechanically strong
5. Preferred for low speed alternators	Preferred for high speed i.e. turbo alternators
6. Primemovers used are water turbines, IC engines.	Primemovers used are steam turbines, electric motors.
7. Separate damper winding is provided.	Not necessary
8. For same size, the rating is smaller than cylindrical type	For same size, rating is higher than salient pole type

Induced EMF:

$E = 4.44\, f\, \phi\, T\, K_p\, K_d$ volts

E is the rms emf per phase.

ϕ = flux per pole

$f = \frac{NP}{120}$ f is the frequency

P = number of poles

N = rotor speed in rpm.

Distribution factor, $K_d = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}}$

where m = no. of slots / pole

b = slot angle

$= \frac{180}{n}$

where n = no. of slots/pole

pitch factor $K_p = \cos\frac{\alpha}{2}$

where a = 180° - coil span

Voltage drop in Alternator:

The drop is due to the following:

a) Drop in the resistance of the winding.

b) Drop in the reactance of the winding.

c) Drop due to armature reaction.

$$E = \sqrt{(V_{ph}\cos\phi + I_a R_a)^2 + (V_{ph}\sin\phi \pm I_a X_s)^2}$$

\+ for lagging power factor

\- for leading power factor

Voltage Regulation:

% regulation = $\frac{|E|-|V|}{|V|} \times 100$

where E = no-load emf

V = terminal voltage

Synchronous Motors:

Synchronous motor is similar in construction to the alternator. It has a stator which houses the three-phase winding and a rotor which consists of electromagnetic poles. The rotor can be either salient pole type or non salient poll type.

The rotor poles are normally excited by a small dc shunt generator called the pilot excited or by any other suitable dc source.

The working of the synchronous motor depends on the factor that when a three phase supply us given to the three-phase stator winding, a rotating magnetic field is produced.

Characteristics of Synchronous motor:

1. It runs only at synchronous speed. The speed of the motor can be changed by changing the frequency only.

$N_s = \frac{120f}{p}$

2. It is not inherently self-starting motor.

3. It is capable of operating under wide range of powerfactor, either lagging or UPF or leading.

Starting Methods of Synchronous Motor:

1. A dc motor coupled with synchronous motor shaft.

2. A small induction motor of at least one pair of poles less than synchronous motor.

3. Using damper winding.

Applications:

1. Synchronous motors are used where constant speed is desired.

2. When over excited, synchronous motors are useful for power factor improvement of lagging industrial loads.

3. They can be used for improving the voltage regulation of long transmission lines.

Transducers:

An electronic instrumentation system consists of a number of components to perform a measurement and record its results.

It consists of three major components:

i) an input device

ii) a signal conditioning or processing device

iii) an output device

Transducer when actuated transforms energy from one form to another.

Electric Transducers:

In order to measure non-electrical quantities a detector is used which usually converts the physical quantity into displacement. This displacement actuals an electric transducer which acting as a secondary transducer, gives an 0/P that is electrical in nature.

A transducer may be defined as a device which converts energy from one form to another.

Another name for a transducer is pick up.

Classification of Transducers:

Classified on the basis of transduction form used,

i) as primary and secondary transducers.

ii) as passive & active transducers.

iii) as analog and digital tranducers.

iv) transducers and inverse transducers.

Passive transducers:

Passive transducer derives the power required for transduction from an auxiliary power source. They also device part of the power required for conversion from the physical quantity under measurement. They are also known as externally powered transducers.

Ex: resistive, induce and capacitive transducers

Active transducers:

Active transducers are those which do not requirs auxiliary power source to produce their output. They are also known as self generating type since they develop their own voltage or current output.

Example: Tachogenerators, thermocouples, photovoltaic cells and piezo electric crystals.

Analogy transducer:

Analog transducer convert the input quantity into an analog output which is a continuous function of time Thus a strain gauge, an L.V.D.T a thermocouple or a thermostat may be called as analog transducers as they give an O/P which is a continuous function of time.

Digital Transducers:

Digital Transducers convert the input quantity into an electrical O/P which is in the form of pulses.

Inverse transducers:

Inverse transducers is a device which converts an electrical quantity into a non-electrical quantity.

Analog Ammeters, voltmeters and Ohmmeters:

Main type of instruments used as ammeters and voltmeters are:

1. Permanent magnet moving coil (PMMC) - only used for dc.
2. Moving iron - measures only rms value - ac and dc.
3. Electro-dynamometer - to measure both ac and dc.
4. Hot wire - measures rms value and used for both ac and dc.
5. Thermocouple - measures rms value and used for both ac and dc.
6. Induction type instrument - used for ac only.
7. Electrostatic type instrument - used only for voltage measurement both ac and dc.
8. Rectifier type instrument - measures average value.

Instrument Transformer:

In power systems, currents and voltages handled are very large and therefore direct measurements are not possible BS these currents and voltages are far too large for any meter of reasonable size and cost. Hence these currents and voltages are stepped down with the help of instrument transformer so that they could be metered with instrument of moderate sizes.

Transformation ratio.

$$R = \frac{\text{Primary winding voltage / current}}{\text{Secondary winding voltage / current}}$$

Nominal ratio,

$$K_n = \frac{\text{Rated primary winding current / voltage}}{\text{Rated secondary winding current / voltage}}$$

Turns ratio, n

$n = \frac{\text{Number of turns of Secondary winding}}{\text{Number of turns of Primary winding}}$ for a CT

$= \frac{\text{Number of turns of primary winding}}{\text{Number of turns of secondary winding}}$ for a PT

Galvanometers:

A galvanometer is an instrument used for detecting presence of small current or voltage in the circuit or for measuring their magnetitude. A galvanometer should be sensitive, should have a stable zero, a short periodic time and nearly critical damping.

D'Arsonval Galvanometer:

Reflecting torque. $T_d = Gi$
where
G = NBA = NBld = displacement constant of galvanometer
i = current through moving coil
Current sensitivity. $S_i = \frac{\theta_i}{i}$
where θ_F = Final steady deflection

Measurement of Power:
Electrodynamometer Wattmeter:
In these type of instruments there are two coils, one fixed coil and other moving coil. Fixed coil is called current coil and moving coil is called pressure coil.
Averrage value of deflecting torque is given as,
$$T_d = \frac{VI}{R_p} \cos\phi \frac{dM}{d\theta}$$
where
V and Z = Instantaneous values of voltage and
current being measured.
ϕ = Load power factor
R_p = Resistance for pressure coil circuit
θ = Final steady deflection

Measurement of Energy:
Energy meter for A.C. Circuit:
Induction type energy meters are universally used for measurement or energy in domestic and industrial ac circuits.

Creeping:
In some meters a slow but continuous rotation is obtained even when there is no current flowing through the current coil and only pressure coil is enersized. This is called creeping. The major cause for creeping is overcompensation for friction. In order to prevent creeping two diametrically opposite holes are drilled in the disc.

Measurement of phase and Frequency with CRO:
- When two sinusoidal voltages are simultaneously applied to horizontal and vertical plates of CRO, a characteristic pattern is obtained on the CRT screen which is called as Lissajous pattern.
- When two sinusoidal voltage of equal frequency which are in phase with each other are applied to the horizontal and vertical deflection plates, the pattern appearing on the screen is a straight line.
- When two equal voltages of equal frequency but 90° phase displacement are applied to a CRO, the trace on the screen is a circle.

When two equal voltages of equal frequency but with a phase shift <J> [not equal to 0 or 90°], we obtain an ellipse. A ellipse is also obtained when unequal voltages of same frequency are applied.

Frequency measurement:

$$\frac{f_y}{f_x} = \frac{\text{Number of times tangents touches top or bottom}}{\text{Number of times tangents touches either side}}$$

$$\frac{f_y}{f_x} = \frac{\text{Number of intersection of the horizontal line with the curve}}{\text{Number of intersection of the vertical line with curve}}$$

Digital Voltmeter:

A digital voltmeter converts the analog voltage into a. BCD form which is then decoded and displaced on some form of readout such as seven segment decoder.

FSV - (Full Scale Voltage):

It represents maximum O/P voltage for the D/A converter and is obtained when all bits of digital input are 1. O/P for any bit,

$$e_0 = \frac{V_R}{2^n}$$

where n = number of bits

If there are n, bits,

$$FSV = \frac{V_R}{2^1} + \frac{V_R}{2^2} + \cdots + \frac{V_R}{2^n}$$

$$FSV = V_R\left[1 - \frac{1}{2^n}\right]$$

Resolution:

$$\%\ \text{resolution} = \frac{\text{Step size}}{\text{F.S.V}} \times 100 = \frac{1}{2^n - 1}$$

Types of Digital Voltmeters:

i) Ramp type DVM

ii) Integrating type DVM

iii) Continuous balance DVM

iv) Successive approximation DVM

Electronic Voltmeters:

Electronic voltmeters or ammeters use amplifying rectifier and other auxiliary circuits to produce a current proportional to the quantity being measured and this current is measured by a PMMC instrument.

A differential amplifier is the basic component of all electronic voltmeters.

Storage Oscilloscope:

Analog Storage Oscilloscope:

Storage is done in analog form. Storage is useful in analyzing transient signal. Analog storage is capable of higher speed but is less versatile than digital storage.

Digital storage Oscilloscope:

The basic oscilloscope still remains along and uses an analog storage CRT. A digital CRO digitizes the input signal so that all the subsequent signals are digital. A conventional CRT is used and storage occurs in electronic digital memory. The input signal is digitized and stored in memory in digital form. In this state it is capable of being analysed to produce a variety of different information. To view the display on

CRT, the data from memory is reconstructed in analog form.