Section-B
Lecture-1

- Introduction:
- Magnetic circuits : MMF calculation for airgun and iron parts of electrical machines.
- Gap contraction coefficient real and apparent flux density.
- Leakage flux and reactance calculation for transformer, rotating machines.
- Design of magnet.

General Design Procedure

Sequential steps involved in the design and manufacture of any product:

- Customer specification as per contract, if available, should be read and salient points of design parameters to be highlighted.
- Latest National/International standards applicable for this design should be referred.
- Calculation of main dimensions and subsequently dimensions of each part and Performance parameters, using well-proven computer programs, established with equations, scientific formulae, empirical formulae based on previous experience, curves, tables, charts, etc.

Conti…

- Ensuring that the volume and weight of the product do not pose any problem for
- either manufacture at works or transport to site or erection and commissioning at site.
- Any foreseen problems should be solved before the related activity begins.
- Preparation of the specifications of each type of materials used in the product.

Conti…

- Preparation of drawings of each part and furnishing to manufacturing shops, Purchase department for purchase of raw materials, tools and sub-contracted items.
- Writing of process (Sequential steps involved): How to manufacture each part, clearly indicating the types of tools, machines, workmen, etc.
- Writing of process: How to sequentially assemble each part/component.
- Writing the process how to carry out tests on each component and fully assembled machine to check the quality as specified by standards.
- Manufacturing the components and carrying out in-process tests.

Conti…

- II. All components are assembled and testing has to be carried out on full machine
- If it is a new design, additional tests (type tests) to be done over and above the normal routine tests specified.
- Dispatching the machine to customer site where it is erected and commissioned to keep ready for normal operation.
- Loading the machine at rated conditions and checking the performance.

Steps to Get Optimal Design

- (a) Input parameters like KW, Voltage, PF, Frequency, and any parameter guaranteed
- to customer etc., to be kept constant.
- (b) Operating range (minimum and maximum values) of various input design
- parameters to be selected (like Flux densities, Current densities etc.)
- (c) Maximum and minimum values of certain output parameters to be incorporated
- (like number of stator slots, % Regulation etc.)

Conti…

- (d) A well proven computer program is run to print out various possible alternative designs.

- (e) Optimization criteria to be identified. (like lower cost, lower weight, lower Kg/KVA, Higher efficiency, lower temp-rise, etc.)

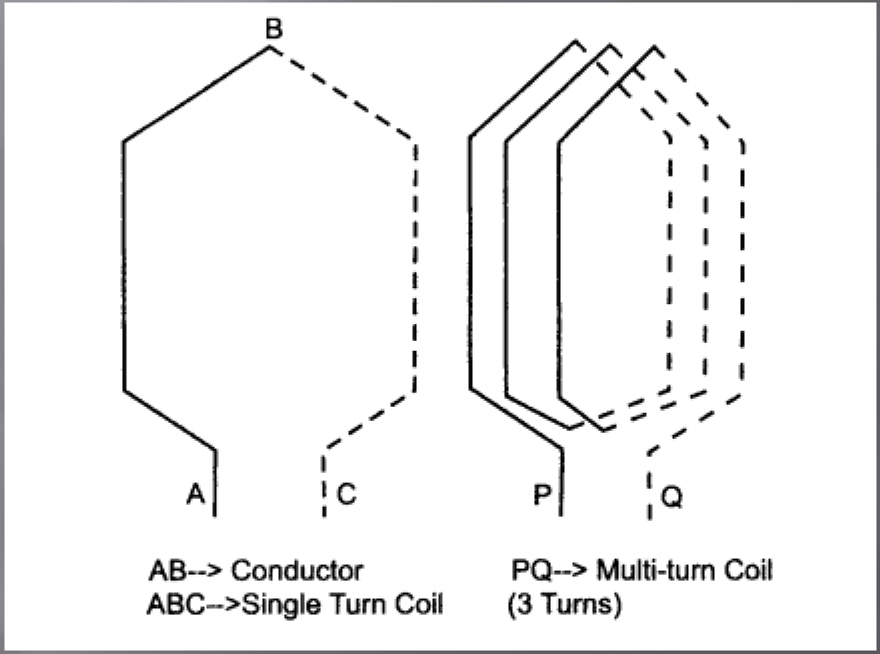
- (f) Optimal design is selected to suit the optimization criteria.

Lecture-2

Important Terms Related to Armature Windings :

- (a) Conductor: Active length of winding wire or strip in a slot.
- (b) Turn: A turn consists of two conductors placed inside separate slots on the armature periphery approximately a pole pitch apart as shown in below fig.
- conductors lie under opposite poles so that emf induced in the turn is additive.
- (c) Coil: A coil may consist of one or more number of turns connected in series. If it contains two or more number of turns, it is called a multi-turn coil.

Coil:


B
A
C
P
Q
AB--> Conductor
ABC-->Single Turn Coil
PQ--> Multi-turn Coil
(3 Turns)

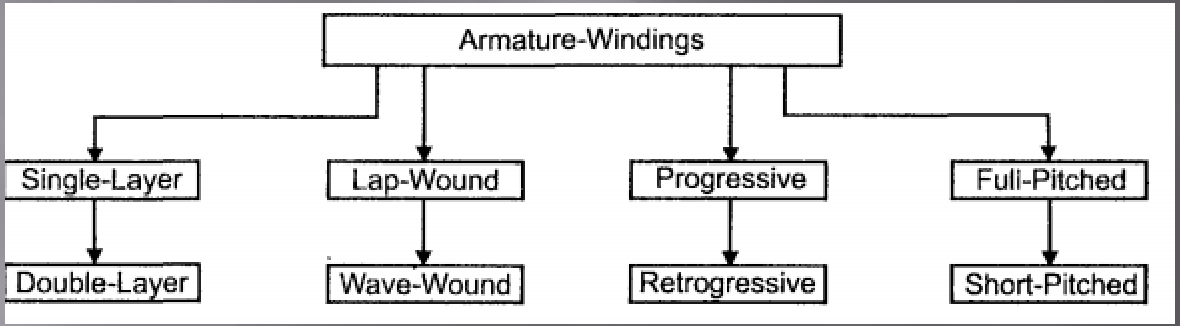
- (d) Coil-side: A coil consists of two coil sides, upper or lower coil sides placed in
- two different slots, approximately a pole pitch apart.
- (e) Over-hang: End portion of coil connecting the two conductors or coil sides is
- called overhang winding.
- (t) Coii-Span: Distance measured in a number of slots between two coil sides of a
- coil placed in slots over the periphery of the armature.

Conti…

- (g) Full Pitch Coil: If the coil span is exactly equal to a pole pitch (=slots/pole) then it is full pitched coil.

- (h) Short Pitched coil/Chorded coif: If the coil span is not equal to a pole pitch (usually less only) then it is called Short pitched coil.

Classification of armature winding



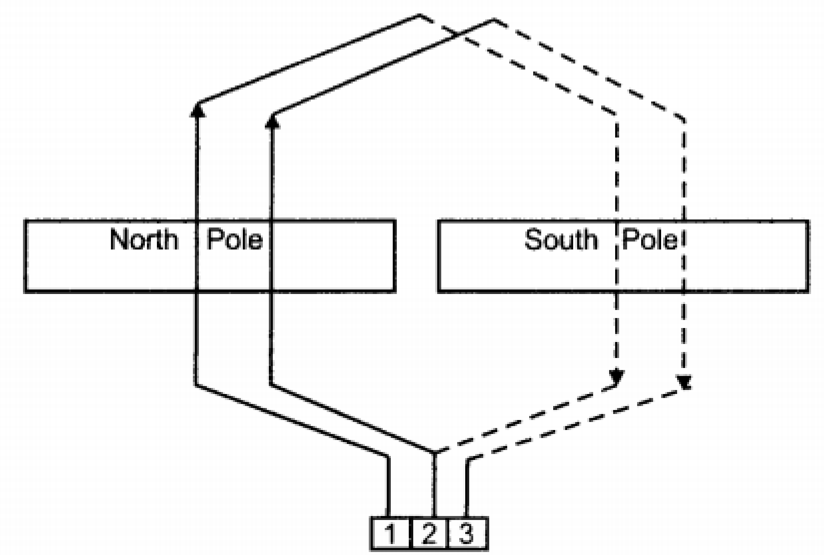
- (a) Single-Layer: Slot contains only one conductor or one coil side

- (b) Double-Layer: Slot contains two coil sides. Top/upper coil side of a slot (A) in Fig. connected to bottom/lower coil side of another slot (B) which is approximately one pole pitch away and bottom/lower side of slot (A) connected to top/upper coil side of another slot (C) which is approximately one pole pitch away.

- Lap-Winding:]f both the coil sides are connected to adjacent commutator
- segments, say, I and 2 as shown in Fig. 3.3, and further connections are made
- in this manner, it is called simple Lap-winding. Here commutator pitch is unity (± 1).
- It is to be noted that both first and second coils connected in series lie under same set of poles. For machines designed for higher currents more number of parallel paths are required. Then it is called Multiplex Lap winding.
- For example, if two parallel paths are provided, it is called Duplex Lap winding and commutator pitch is (±2).

Lecture-3

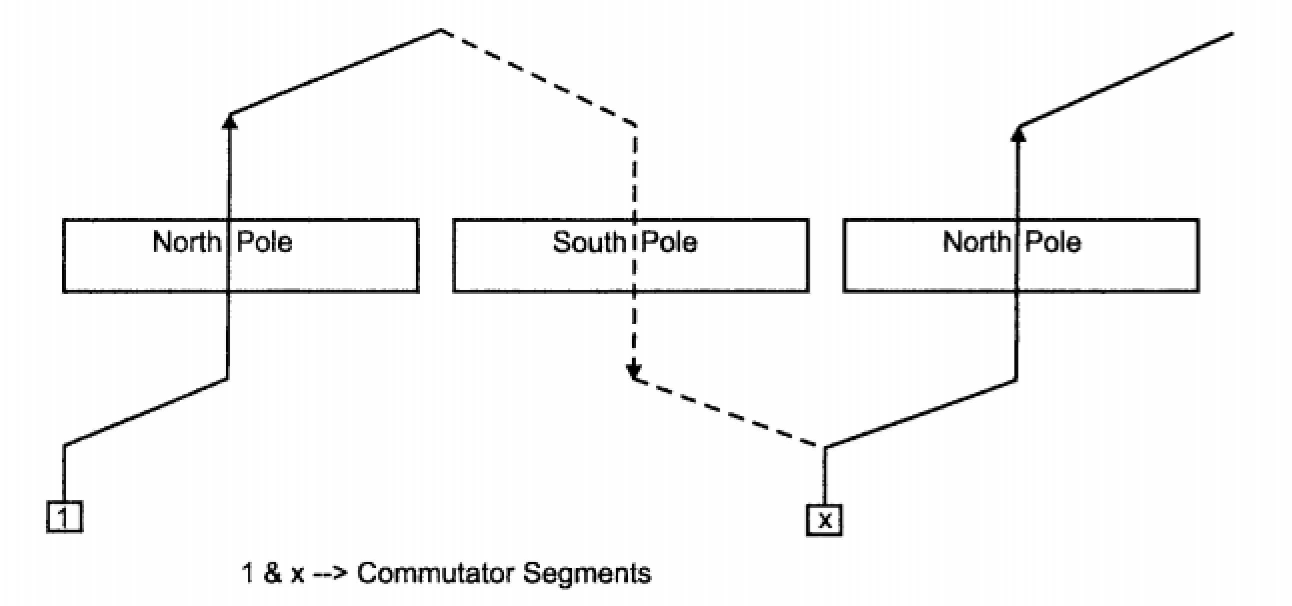
Wave winding:



1, 2 & 3 --> Commutator Segments

- Wave-Winding:]f both the coil sides are connected to commutator segments which are approximately two poles pitches apart (actually the winding pitch depends on number of poles and number of commutator segments?, say, I to X)as shown in and further connections are made in this manner, it is called simple Wave-winding.
- it is to be noted that first and second coils connected in series lie under different set of poles. For machines designed for higher currents more number of parallel paths are required. Then it is called Multiplex Wave winding.
- For example, if two parall~1 paths are provided, it is called Duplex Wave winding

Wave winding



- (e) Progressive Winding: Back pitch (Yb) is higher than the front pitch and
- winding progresses in clock-wise direction when viewed from commutator end.
- (f) Retrogressive Winding: Front pitch (Yf) is higher than back pitch and winding
- progresses in Anti-clockwise direction when viewed from commutator end.
- (g) Full Pitched Winding: If the coil span is exactly equal to a pole pitch(=slots/pole) then it is full pitched coil.
- (h) Short Pitched Winding/Chorded Winding: If the coif span is not equal to a pole
- pitch (usually less only), then it is called Short pitched coil.

- Winding Pitches (Refer above Figures)
- (a) Back pitch (Yb): Distance between two coil sides of the coil at the back of the commutator is called Back pitch.
- (b) Front pitch (Yf): Distance between finish of a coil and the starting of next coil which are connected to same commutator segment, is called Front pitch.
- (c) Resnltant pitch: Distance between starting of two consecutive coils is called resultant pitch (Yr).
- For Lap Winding: Yr =Yb - Yf.
- For Wave Winding: Yr = Yb + Yf.

Winding pitches:

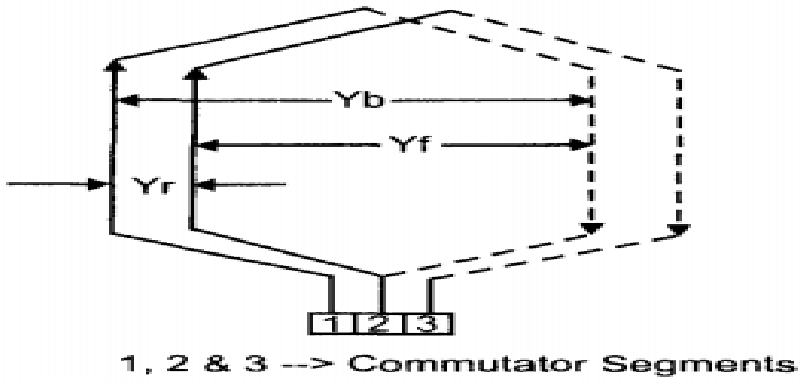
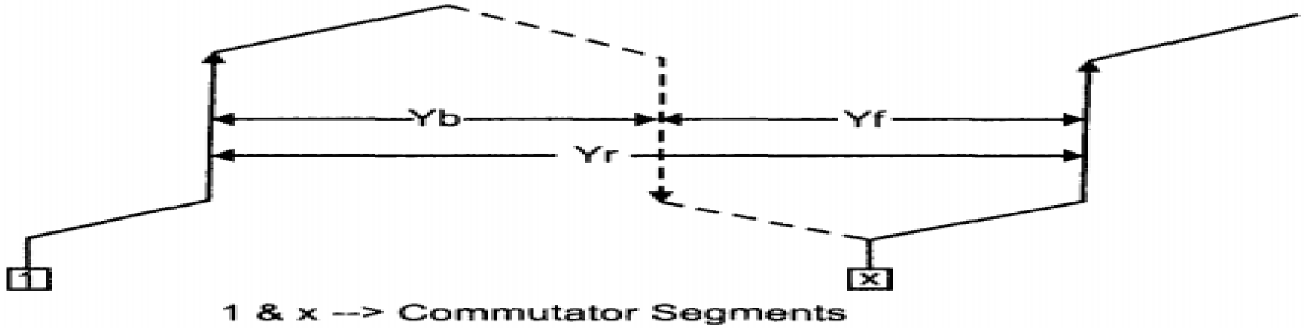


Fig. 3.5



Lecture-4

- Armature Windings for DC Machines
- Rules for Design Development of Lap-Winding for a DC Armature
- (a) Back pitch (Yb) and front pitch (Yi) are odd. They are not equal. They differ by 2 or multiples thereof. In general Yb = yf ± 2m, where "m" is the plex of the winding (1 for simplex, 2 for duplex, 4 for quadraplex etc.)

- If Yb = yf + 2m, it is progressive winding and If Yb = Yf - 2m, it is
- retrogressive winding.
- Both yf and Yb should be nearly equal to pole pitch.

- total number of conductors and "P" is the number of poles.
- Resultant pitch (Yr) = Yb - Yf will always be even since arithmetical difference of two odd numbers is even. Number of coils is equal to number of commutator segments.

- Number of parallel paths in armature is equal to "mP", where "P" is number of
- poles and "m" is the plex of winding.
- Commutator pitch Y c = ± 1m, "+ I" for progressive and "-I" for retrogressive
- windings.
- Yb = Z + I and Yf = Z -I for Progressive winding
- and Yf= Z +1 for Retrogressive winding.

Rules for Design Development of Wave-Winding

- (a) Back pitch (Yb) and front pitch (Yf) are odd. They may be equal or differ by 2.
- Both yf and Yb should be nearly equal to pole pitch.
- (b) A h(Y) Z±2 Z/2±1 No.ofCommutatorBars±1
- (c) Resultant pitch (Yr) = Yb + yf
- (d) Commutator pitch Yc = Ya
- (e) No. of coils is equal to no. of commutator segments
- (f) No. of parallel paths in armature is equal to "2m" where "m" is the plex of winding

- In actual transformer design , the constants for the ideal circuit are determined from tests on materials and on transformers.
- For example , the resistance component of the core loss, usually called no-load loss, is determined from curves derived from tests on samples of electrical steel and measured transformer no-load losses.
- The designer will have curves similar for the different electrical steel grades as a function of induction. Similarly , curves have been made available for the exciting current as a function of induction.
- A very important relationship is derived from Equation 1.11. It can be written in the following form:
- $B=0.225\ (E/N)/(f\ A)$

Lecture-5

Leakage Reactance:

- Additional concepts must be introduced when the practical transformer is considered,. For example the flow of load current in the windings results in high magnetic fields around the windings .

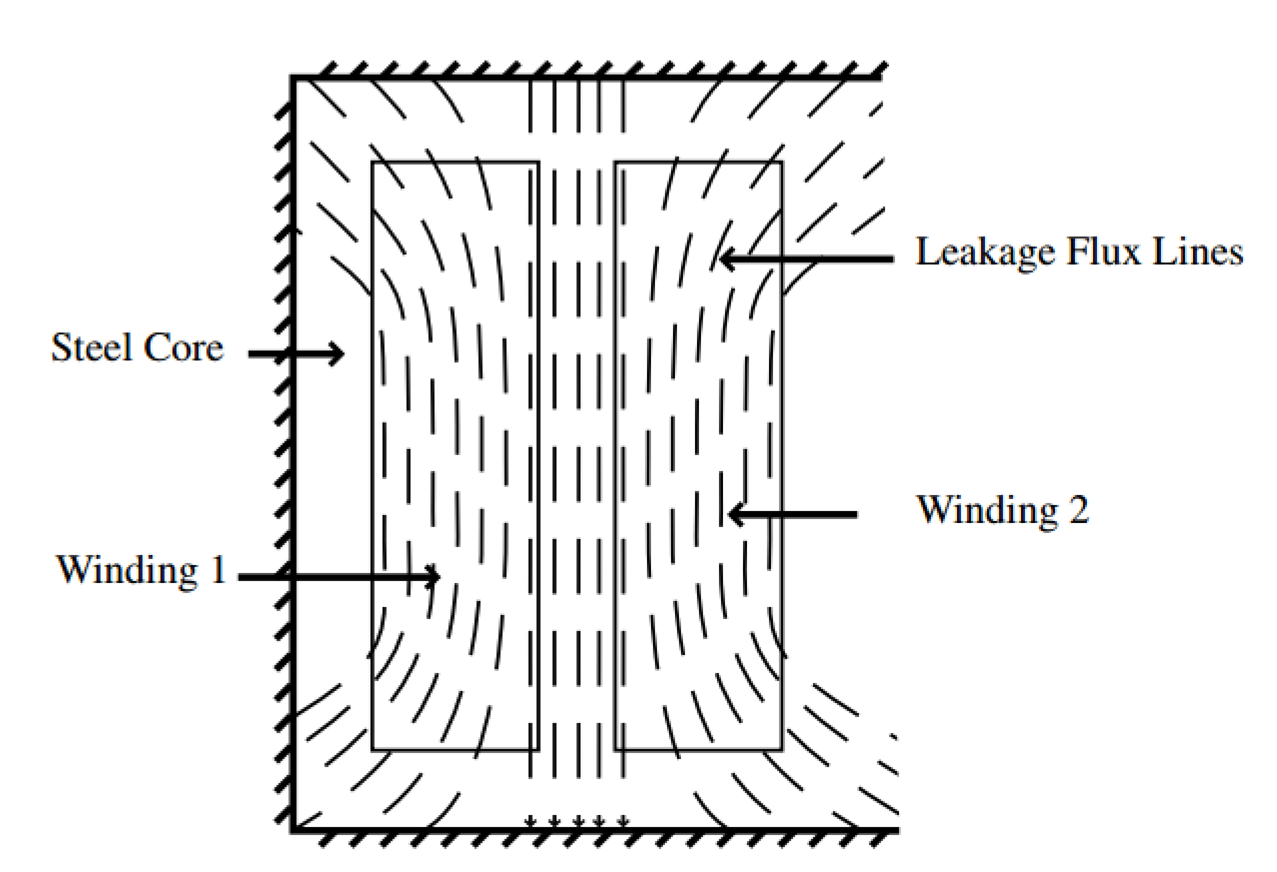
- These fields are termed leakage flux fields . The term is believed to have started in the early days of transformer theory, when it was thought that this flux “leaked “out of the core . This flux exists in the spaces between windings and in the spaces occupied by the windings , as seen in Figure

- .

Conti…

- These flux lines effectively result in an impedance between the windings, which is termed “leakage reactance” in the industry. The magnitude of this reactance is a function of the number of turns in the windings, the current in the windings, the leakage field, and the geometry of the core and windings. The magnitude of the leakage reactance is usually in the range of 4 to 20% at the base rating of power transformers

Transformer core and winding:



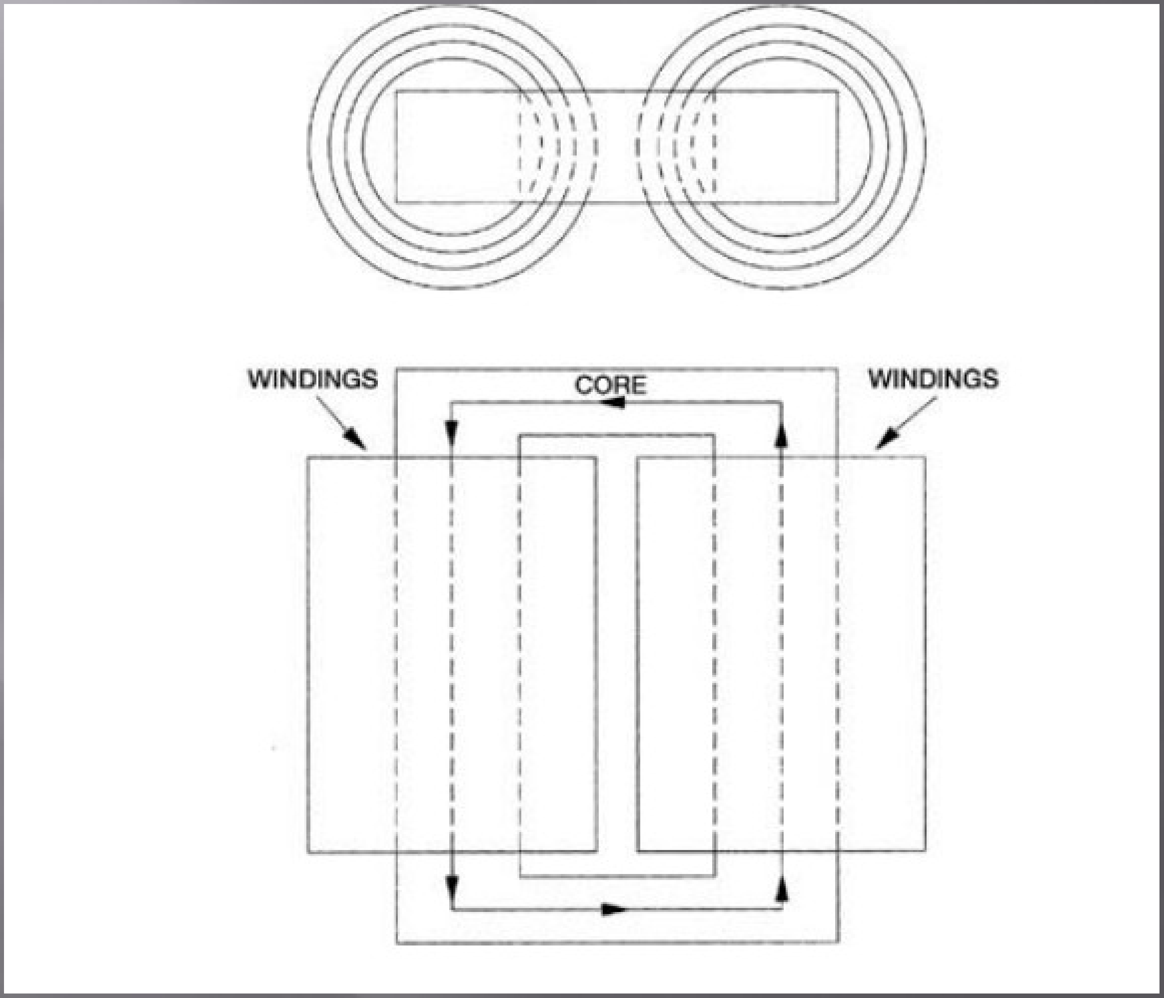
- Load Losses
- The term load losses represents the losses in the transformer that result from the flow of load current in
- the windings. Load losses are composed of the following elements.
- • Resistance losses as the current flows through the resistance of the conductors and leads
- • Eddy losses caused by the leakage field. These are a function of the second power of the leakage

field density and the second power of the conductor dimensions normal to the field.

- • Stray losses: The leakage field exists in parts of the core, steel structural members, and tank walls.
- Losses and heating result in these steel parts.

- Again, the leakage field caused by flow of the load current in the windings is involved, and the eddyand stray losses can be appreciable in large transformers.
- In order to reduce load loss, it is not sufficient to reduce the winding resistance by increasing the cross-section of the conductor, as eddy losses in the conductor will increase faster than joule heating losses decrease.
- When the current is too great for a single conductor to be used for the winding without excessive eddy loss, a number of strands must be used inparallel.

Cross section view of transformer



Limbs of the tranformer

5 “E”-assembly, prior to addition of coils and insertion of top yoke.