ELECTRICAL INSULATION IN POWER APPARATUS

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Materials Used in Power Apparatus

- Insulating Materials
- Conducting Materials
- Magnetic Materials
- Contact and Resistive Materials

Requirements

- Technical Function (TEAM)
- Technological Properties (Workability, Homogeneity, Dimensional Stability)
- Economic Aspects

- Majority of the outages on power systems are due to insulation failure
- Though the insulation costs account for only 15% of the total apparatus cost, proper functioning of the insulation is vital.
- Purpose of Electrical Insulation
  - Confine the current to intended paths
  - Act as a heat sink
  - Sometimes as a mechanical support too

- Electrical Insulation for Different parts of the power apparatus
  - Between coils of different phases
  - Between each coil and earth
  - Between turns of a coil
  - Between coils of the same phase
- Specific Requirements
  - Depends on the application
  - Low loss
  - High Efficiency
  - Environmentally safe

- Classified according to form
  - Solid
  - Liquid (dielectric properties can be partly recovered after breakdown)
  - Gaseous(dielectric properties can be fully recovered after breakdown)
  - Vacuum
  - Composite (Combined)
- Broad Chemical Classification
  - Organic
    - Natural
    - Synthetic
  - Inorganic
    - Natural
    - Synthetic

- Self restoring / Non Self restoring

- Properties of Electrical Insulation
  - Dielectric Property: Capacitance and the loss factor
  - Electrical Property: Insulation Resistance and Dielectric Breakdown
  - Thermal, Mechanical and Chemical properties.

- Thermal Classification of Solid Insulating Materials
  Class O upto 90^0C (Cotton, unimpregnated paper)
  - Class A upto 105^0C (Phenolic resins, enamel varnishes)
  - Class B upto 130^0C (Mica, Asbestos)
  - Class F upto 155^0C(Epoxy bonded Mica)
  - Class H upto 180^0C (Fibre Glass and Silicone Compounds)
  - Class C no limit specified(quartz, glass)

Gaseous Insulation

- Atmospheric air – most common provides the basic insulating function in all electrical components. Main insulation for overhead transmission. Air has low dielectric strength (21.1kV/cm rms).

- Other popular gaseous insulants:
  - Compressed air-higher dielectric strength
  - SF_6 Sulphur HexaFluoride (electronegative gas)
    - Dielectric strength is twice as much as air
    - Offers excellent thermal and arc interruption characteristics.
  - Gas mixtures having comparable breakdown strength and economical at the same time. N_2, CO_2,,Air, N_2O etc have been investigated. The mixture of SF_6 and N_2 has found commercial application in switchgear.
- Vacuum also used as an insulation because of its high dielectric strength.

- Liquid Insulation
  - Mineral Oils(Transformer Oil)
  - Synthetic Hydrocarbons (Polyolefins, used in power cables)
  - Silicones Fluorinated Oils
  - Phosphate esters, fluorocompounds and biphenyls (Castor Oil –a natural ester)
  - Elemental liquefied gases
- Properties of Liquid insulants for power apparatus
  - Efficient coolant
  - Low resistivity ,low loss tangent, high dielectric strength
  - Non Inflammable
  - Chemically stable ,Non toxic and biodegradable

- Good Arc quenching properties
- Good lubrication , low gas absorption and low coefficient of expansion

Solid Insulation

- In earlier times naturally available materials like : cotton,paper, rubber, asbestos
- Synthetic Insulating Materials –Polymeric based materials caused a major revolution in the Electrical insulation industry.
- Polyester (PVC,XLPE,Teflon,PP) Synthetic Resin systems (epoxy), synthetic elastomers, phenolic resins (bakelite)

Composite Insulation

- Solid/Liquid
- Solid/Gas
- Solid/Solid

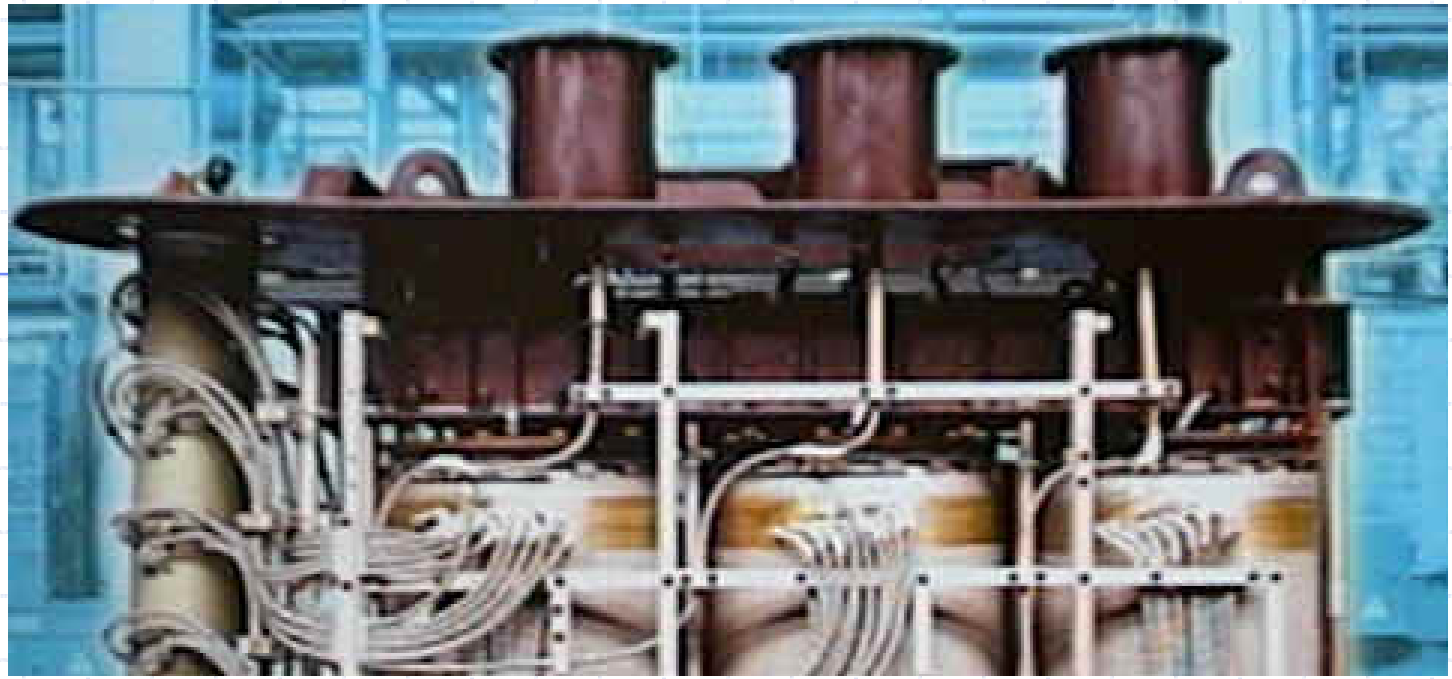
- Power Apparatus
  - Generators , Motors—Rotating Machines
  - Switchgear
  - Transformers (Generator Transformer, Substation Transformers, Instrument transformers and Distribution Transformers)
  - Power Capacitors
  - Power Cables
  - Overhead Insulators
  - Bushings

Insulation in Power Transformers

- Primarily Oil/Paper Pressboard
  - Oil provides the required dielectric strength and insulation and also cools the transformer by circulating through the core and coil.
  - Sludge formation is limited by filling the air space with nitrogen / providing oxygen absorbers like clay or alumina
- Turn to Turn insulation –paper or glass tape
- Coil to coil insulation Kraft paper/Press board

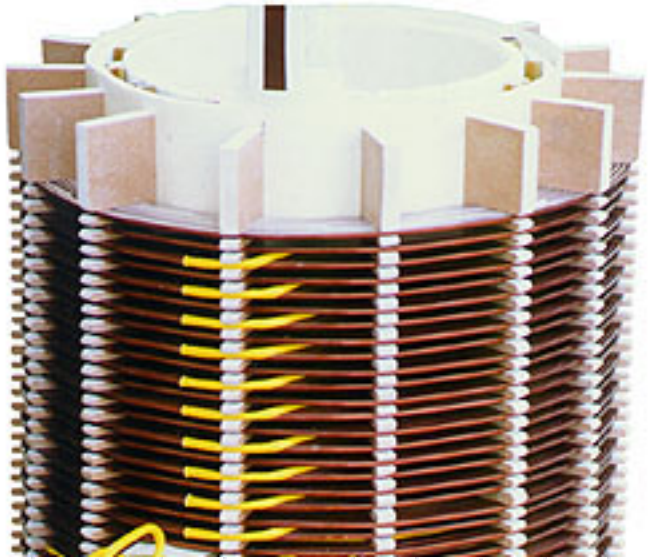
- Low voltage coil/ High Voltage coil to earth insulation Solid tubes spaced in oil
- Gas Insulated Power Transformers use aluminum conductors for windings with polymer film like mylar as turn to turn insulation. SF6 gas insulates all the major gaps.
- Dry type transformers- Cast Epoxy and completed sealed, for instrument transformers.

Dry Type Transformer



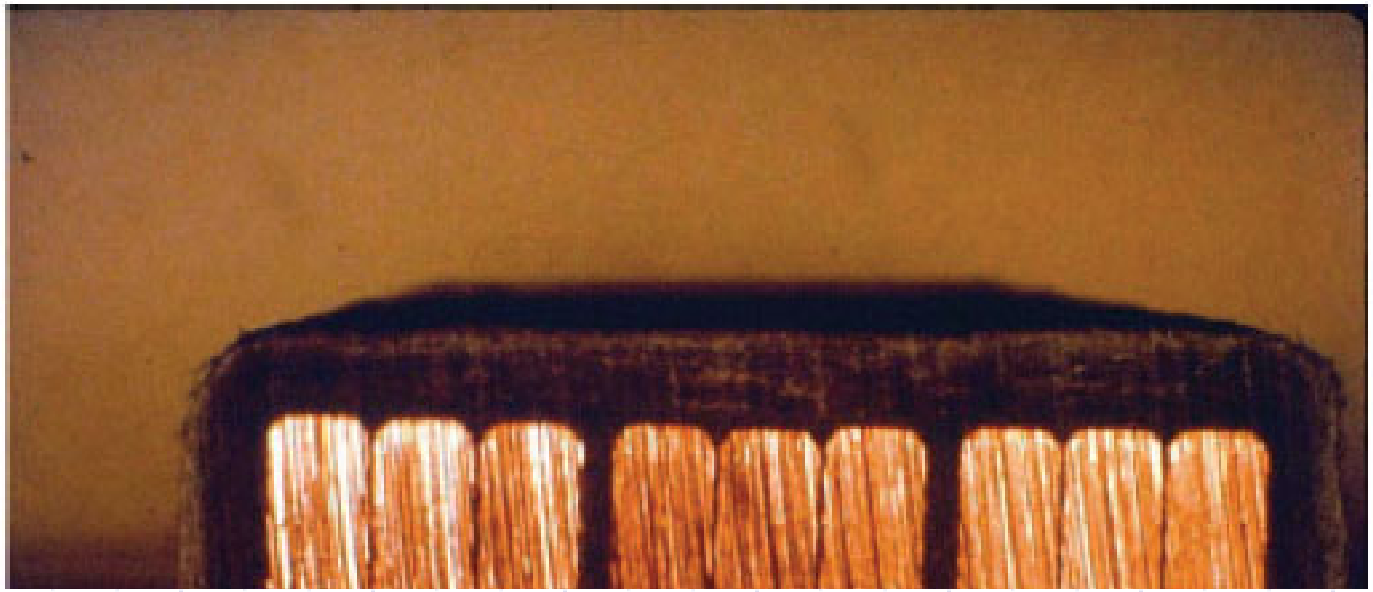
Oil /Paper/Press board Insulation

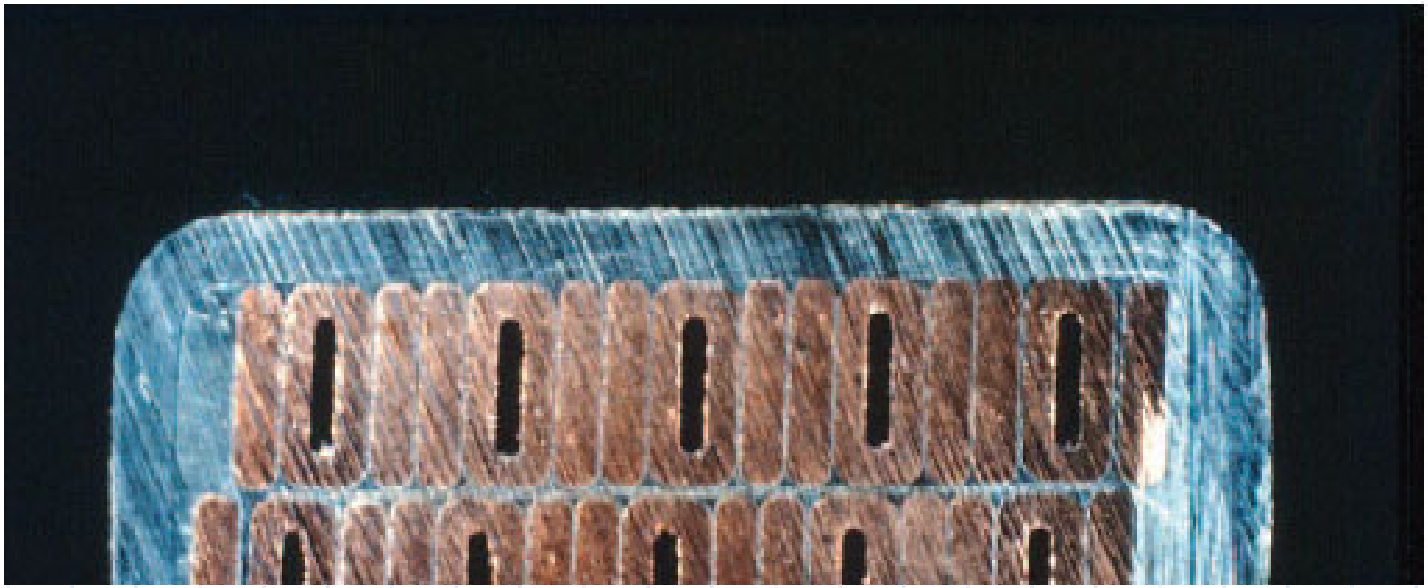
Pole Mounted CSP transformer



Coil of Transformer

- Rotating Machines (Motors, Generators)
  - The selection of the right type of insulation depends upon the rating.
  - Primarily Dry type.
  - Rotor insulation – Single layer of glass fabric,varnished coils wound over the rotor.
  - Stator insulation– MICA. Coil and the slot—Class F (> 155) epoxy bonded Mica tape. Glass tape/ varnish for inter turn insulation. Additional insulation on the overhang portion. Epoxy fibre glass strip is used as a slot wedge

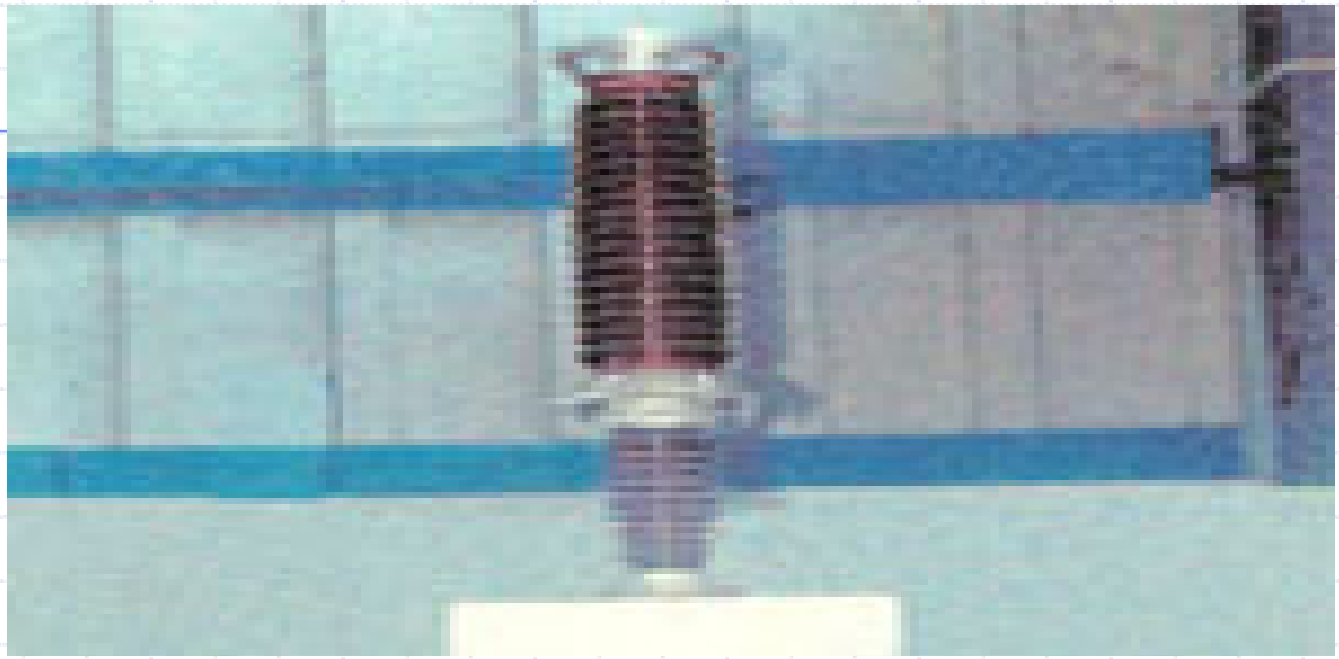




Stator of a High Voltage Rotating Machine

Insulation for Circuit Breakers

- Interrupts the circuit when the critical voltage or current is exceeded
- Low Voltage –Dry Type Moulded
- Vacuum upto 33kV
- Compressed Air/Oil Filled
- Pure SF6 --expensive
- Modern Trend is to use SF6/N2
- Solid Insulating materials must be used for potting, encapsulation and moulding.
- Teflon, Epoxy, polyurethane are widely used.



Outdoor Circuit Breaker, Control and busbars

Insulation for Power Cables

- Natural rubber has now been completely replaced by synthetic rubbers and plastics
- Temperature, elongation and tensile strength are the primary factors

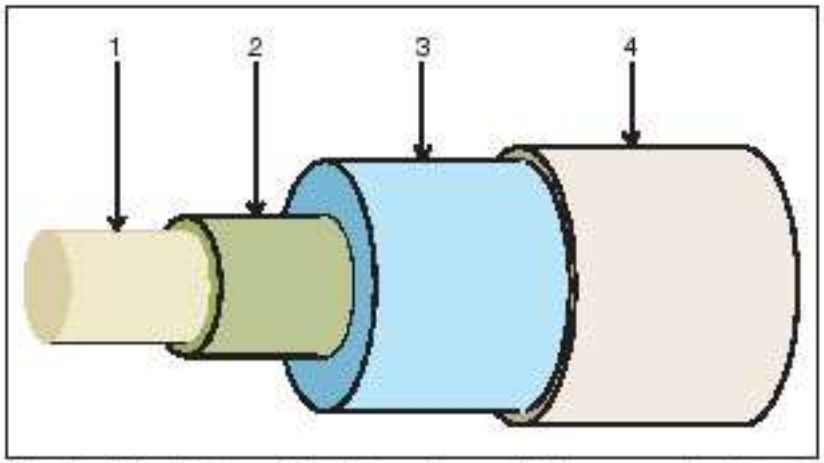


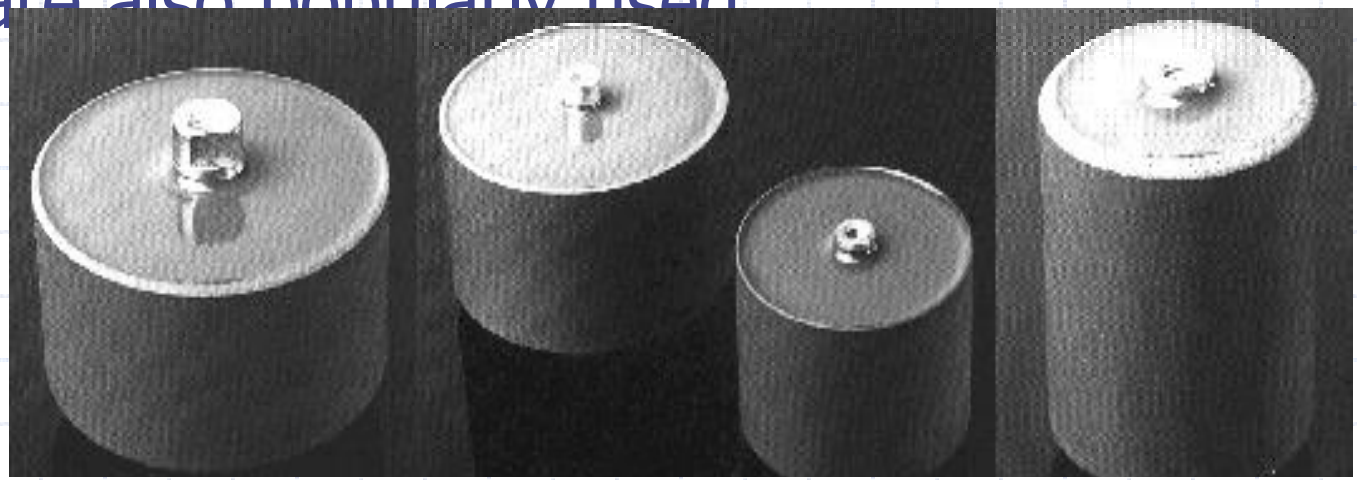
Fig. 1. HV winding-cable (1) conductor; (2) inner semiconducting layer; (3) XLPE insulation; (4) outer semiconducting layer.

- Paper Insulated and Lead sheathed (PILC) (with out oil used upto 100kV with oil upto 400kV, 85 C)
- PolyVinylChloride (PVC) used upto 600V , maximum temperature rise 105 C
- Cross linked Polyethylene (XLPE) upto 400kV with a temperature of 105 C
- Elastomeric cables –Ethylene propylene rubber , Silicone Rubber 28 kV and 80 C

Range of Cables

- Power Capacitors
  - Power factor correction.
  - Requirement is dielectric losses must be kept low (11kV- 400kV, 0.5 –25kVAR)
  - Several Single units of capacitors with paper/PP as a dielectric and aluminum foil as electrodes are connected in appropriate series parallel combination and placed in a hermetically sealed and then thoroughly dried and impregnated to form the power capacitor.
  - Dielectrics used include paper impregnated with oil.
    - Impregnation fills the minute pores in the solid insulation and also acts as a coolant.

- Recent trend is to use PolyPropylene(higher dielectric strength and low loss) with transformer oil as an impregnant. Drastic reduction in size. Synthetic impregnants like MIPB and PXE are also popularly used



- Overhead Insulators
  - Suspension Insulators—Pin type and Cap type

Primarily Ceramic based, now trend is to use polymeric materials

High Voltage Bushings

- Used to bring out a live terminal through a sufficient clearance
- Condenser or capacitor grading principle is used.
- Insulating material for bushing is paper
  - Resin Bonded Paper
  - Oil Impregnated Paper
  - Resin Impregnated paper (used upto 500kV)
- Use of Fibre glass reinforced plastic /Teflon bushings upto 100kV

Condenser Type Bushing

Terminals of a HV capacitor brought out through a bushing

Thank You