EE3036 SUSTAINABLE AND ENVIRONMENTAL FRIENDLY HV INSULATION SYSTEM

Question Bank

UNIT-I

SUSTAINABLE AND ENVIRONMENTAL ENERGY AND PRODUCTS

1. **Define the following.**

(i) Sustainable and Sustainable energy.

- ✓ That can continue or be continued for a long time.
- ✓ Involving the use of natural products and energy in a way that does not harm the environment.
- ✓ Causing, or made in a way that causes, little or no damage to the environment and therefore able to continue for a long time.
- ✓ **Sustainable energy** comes from renewable sources, so it respects natural resources, and its production process does not generate an environmental impact or the emission of greenhouse gases or other pollutants.

(ii) Environmentally Friendly.

- ✓ Not harmful to the environment, or trying to help the environment.
- ✓ The production system must be economically and socially acceptable, and also nature- and *environment-friendly*.

2. **Define sustainable and environmental friendly insulating materials.**

Sustainable and environmentally friendly insulating materials are continuously substituting conventional insulating items in the market place. These are favourable to traditional insulating materials, due their superior functionality. The also offer explicitly security and eco-friendly advantages.

3. **Describe the high-voltage insulation system.**

HV Insulation System:

- ✓ The primary function of high voltage insulators is to insulate, i.e., prevent the flow of electric current and to keep oppositely charges conductors mechanically separated during all service conditions.

- ✓ This means that the insulation of a power apparatus is designed to withstand any electrical, thermal, and mechanical stress likely to occur during manufacturing, testing, and the long-expected service lifetime of 30 years or more.

4. **List the high voltage apparatus.**

- ✓ Bushings, capacitors and power transformers, Distribution Transformer, circuit breakers, Instrument transformer (current transformer and potential transformer).

5. **State the functions of insulating liquids (oil) in high-voltage equipment.**

This oil basically performs three essential functions, i.e., (1) it electrically offers insulation between different active elements and also performs as a preventive coating film to avoid corrosion of metallic areas; (2) it efficiently removes the heat from core and conductors by the action of conduction and transports heat to enclosing container, that is later discharged outward to the environment (superior heat transfer) and (3) it behaves as a healthiness index for HV equipment.

6. **What are the common challenges related to environmentally friendly insulation fluids for HV applications.**

Common challenges faced by renewable and environmentally insulation applications:

- ✓ Oxidation stability
- ✓ Improving pour point
- ✓ Reducing viscocity
- ✓ Production of vegetable oils

7. Define carbon print.

A carbon footprint (or **greenhouse gas footprint**) is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.

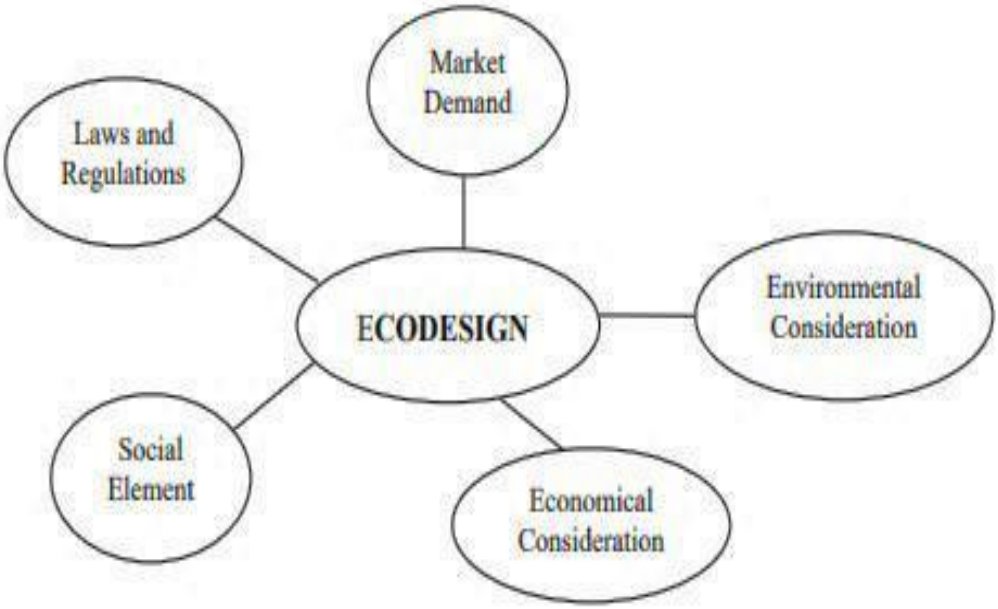
8. State global warming potential.

The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2).

9. List out the Causes Global Warming Potential.

Burning fossil fuels, cutting down forests and farming livestock are increasingly influencing the climate and the earth's temperature. This adds enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming.

10. What are the influence factors of environmentally friendly design?



UNIT-II

ALTERNATE GREEN GASEOUS INSULATORS

1. Define SF6 gas and its properties.

Sulfur hexafluoride (SF6) gas is colourless, odourless gas with a vapour density five times that of air.

SF6 is an anthropogenically produced compound, mainly used as a gaseous dielectric in gas insulated switchgear power installations.

Over the years, high voltage (HV) insulation relying on the use of sulfur hexafluoride (SF6) has passed the required qualification tests to become the most commonly used insulating gas in electrical systems.

2. State Toxic by-products of SF_6 in the Working Environment:

In the presence of an electrical discharge such as an arc, spark, or corona, a portion of the SF6 decomposes into lower fluorides of sulfur that can react to form a number of chemically active by-products.

3. Summarize the toxic by-product during the working cycle of SF6.

The most important toxic by-products, as well as their common concentrations observed during the working cycle of SF6 as an insulant, are summarized in Table 1.

Table 1. SF_6 decomposition byproducts and their typical concentrations during repeated sparking. A 16kJ total energy deposition in 70 cm^3 SF_6 gas is examined.[33, 34]

Product	Approximate Concentration (% by volume)
SOF_2 (SF_4)	0.5
SOF_4	0.085
SF_4	0.085
S_2F_{10}	0.025
SO_2F_2	0.006
SO_2	0.002
HF	1.0

4. **Why it is named as green gaseous insulators.**

Green gas for grid (g3) gas, which is an emerging eco-friendly alternative insulation gas for sulfur hexafluoride (SF6) that will be used in gas-insulated power facilities, for reduce environmental concerns.

In recent years, g3 gas-insulated power facilities, including switchgear, transmission line, circuit breaker, and transformer, have been commercially available in the electric power industry.

As for environmental concerns, g3 gas reduces the GWP of more than 94% compared with SF6.

5. **List the importance of green gaseous insulators.**

An environmentally sustainable green gaseous insulation alternative to SF6 should be compliant with the stringent requirements of high-voltage applications. The chemical and physical properties include.

The green Gaseous insulator reduces the environmental impact, such as.

Chemical properties

- ✓ Low GWP;
- ✓ No ozone depletion potential (ODP);
- ✓ Low toxicity; and
- ✓ Non-flammable and nonexclusive.

Physical properties

- ✓ High-dielectric strength;
- ✓ Good arc-quenching capability;
- ✓ High heat dissipation (high thermal conductivity);
- ✓ Low boiling point and high vapor pressure at low temperature;
- ✓ Compatibility with other materials; and Design compactness.

6. **What is the alternate gas of the SF6 gas?**

GE's Grid Solutions business fluoronitrile based gas mixture dubbed 'g3—green gas for grid' has been proven as a suitable replacement for SF6.

7. What is mean by g3?

Grid Solutions, a GE and Alstom joint venture, has identified a ***fluoronitrile based gas mixture dubbed 'g3—green gas for grid***'.

8. How the toxic by-product generate in the SF6 circuit breaker?

The toxic by-product generation rates strongly depend upon the type of the electrical stress (i.e., corona, spark discharge) and the overall operating conditions (i.e., humidity levels, nearby surfaces that can act catalytically, X-ray radiation, or high energy photons, surface to volume ratio, polarity effect).

9. List out the dielectric performance of g3 compare to SF6.

table 1: Dielectric performance of g^3 compared to SF_6 under lightning impulse measured on a 145 kV GIS.

No.	Gas Mixutres	Pressure at 20 °C (bar_{abs})	Desingn Pressure (bar_{abs})	Application (°C)	Standard Deviagtion (kV)	$\frac{U_{50}\,(test)}{U_{50}\,(SF_6)}$
1	100% SF_6	5.5	7	–30	15	1
2	Fluoronitrile/CO_2	6.7	8	–15	14.5	0.94
3	Fluoronitrile/CO_2	6.7	8	–25	14.3	0.87
4	Fluoronitrile/CO_2	7.7	9.5	–25	15.4	0.92
5	Fluoronitrile/CO_2	8.2	~10	–22	12.5	0.96

UNIT III

ALTERNATE GREEN LIQUID INSULATORS

1. Define Green Liquid Insulators.

- ✓ Green insulating liquids Vegetable insulating liquids are a potential alternative to mineral insulating oil for application in HV apparatus, but they also fulfil environmental and health demands, for instance, nontoxicity, biodegradability, recyclability, and non-hazardousness.

- ✓ Undoubtedly, VOs are abundantly available as a natural resource and thought to be green and reasonable insulator.

- ✓ The liquid insulation system is applied both as an insulator and a coolant in several elements of the HV network comprising cables, switchgear and transformers.

2. Characteristics of natural ester-insulating fluids.

Summary of characteristics of **natural ester** insulating fluids applied in HV equipment:

Sl. No.	Features	NE (Natural Ester)
1.	Category	Refined vegetable oil
2.	Major component	Plant-based natural ester
3.	Origin	Derived from crops
4.	Biodegradability	Readily biodegradable
5.	Oxidation stability	Normally oxidation vulnerable
6.	Moisture saturation at ambient (ppm)	1100
7.	Flash point, ºC	>300
8.	Fire point, ºC	>350
9.	Fire categorization	Flash point > 300 _C as per IEC 61100 standard VOs categorized as low-flammability liquids as per IEC standards

3. State the Natural ester oil.

Natural esters developed in the early 1990s in the USA as a “green” and environmentally friendly alternative due to enhanced environmental issues associated with traditional MO and silicon liquids

4. **What are the advantages of the natural ester oil?**

Natural ester liquids indicated adequate dielectric traits, superior chemical stability and lower pour point. They manifested outstanding properties as compared with MO, for instance, higher fire and flashpoint temperatures and superior biodegradability conduct.

5. **Give a comparison of alternating-current breakdown strengths for different insulating.**

Comparison of alternating-current breakdown strengths (AC BDVs) for different insulating liquids.

Experiment	**MO**	**Synthetic Ester**	**NE**	**Silicone Oil**	**Low Viscosity Silicone Oil**
IEC 60,156 2.5 mm	70 kV	>75 kV	>75 kV	50 kV	70 kV
ASTM 1816 1 mm	–	–	37 kV	–	–
ASTM 1816 2 mm	60 kV	–	76 kV	–	–
ASTM D877	55 kV	43 kV	46 kV	43 kV	–

6. **Define biodegradability and toxicity.**

- ✓ Biodegradability is the capacity for biological degradation of organic materials by living organisms down to the base substances such as water, carbon dioxide, methane, basic elements and biomass.
- ✓ The extent to which something is poisonous or harmful.
- ✓ Toxicity refers to the degree to which a specific mixture of substances or chemical substances can cause harm to an organism

7. **What are the major applications and standards of the green insulation system?**

The potential applications for these natural ester (Green Insulation) fluids may include transformers, circuit breakers, cables, tap changers, capacitors and cables, etc. Moisture saturation limits of NEs being extraordinary as they may grasp extra moisture.

The green insulating liquids must satisfy specific universal standards to be applied as insulating channels in the HV apparatus, for instance, HV transformers.

Common acceptance values of characteristics and usual conduct primarily rely on nature and application of fluid, for instance, in distribution transformers and in the HV apparatus.

8. Define oxidation stability.

- ✓ Oxidation stability of dielectric liquids is a crucial factor since this is highly necessary that liquid should not be oxidizing with the passage of time.
- ✓ The reliability of dielectric liquids is considerably influenced by oxidation and aging mechanism that effect openly in equipment's lifespan.
- ✓ The oxidation stability of the insulating fluid is a feature that specifies its resistance to oxidation during operation.

9. What are the benefits of the natural ester oil?

- ✓ The application of NEs as an alternative to MOs has multiple benefits.
- ✓ The dielectric constant of natural ester influences the dielectric constant of paper insulation impregnated with ester liquids that are superior to that of MOs.
- ✓ Because of the closer permittivity values of natural esters and impregnated paper insulation, a greater stress is undergone on paper insulation in the case of natural esters liquids than MOs.
- ✓ To choose appropriate insulating fluids, it is essential to identify the dielectric characteristics: breakdown strength (BDV), dielectric constant, dielectric dissipation factor, etc.

10. Compare the Electrical features of natural ester fluid and mineral oil (MO).

Electrical features	**MO**	**NE Fluid**
Dielectric strength (BDV), kV	54.9	56.7
Dielectric dissipation factor	0.081	0.45
Specific resistance, 10^{12} ohm cm–1@80 ºC	220	**3**
Gassing tendency, µL/min	**-5**	**-79**

UNIT IV

ALTERNATE GREEN SOLID INSULATORS

1. **Define solid insulators.**

- ✓ Solid insulator means the insulating coating of wiring harnesses, provided in order to cover and prevent the high voltage live parts from any direct contact.

- ✓ SOLID DIELECTRICS USED IN PRACTICE Solid insulating materials are used in all kinds of electrical circuits and devices to insulate one current carrying part from another when they operate at different voltages. A good insulator should be of low dielectric loss, having high mechanical strength, free from gaseous inclusions and moisture, and should also be resistant to thermal and chemical deterioration.

2. **What is insulating paper?**

- ✓ Insulation paper mainly includes: plant fiber paper.
- ✓ Plant fiber paper includes cable paper, capacitor paper, winding paper, etc.
- ✓ Example: paper and polymer are organic materials.
- ✓ Solid dielectrics vary widely in their origin and properties. They may be natural organic substances, such as paper, cloth, rubber, etc.

3. **Advantages of Environmental-friendly solid insulating materials.**

The production system must be economically and socially acceptable, and also nature- and *environment-friendly*.

The insulation system generally applied in HV apparatus solid cellulose insulation (paper/pressboard) and liquid insulation for stable functioning.

Solid environmental-friendly insulating materials, have shown great advantages and potential as insulating materials for HVDC cables, including environmental friendliness, high temperature resistance and high breakdown strength.

4. **List out the properties of environmental-friendly insulating material**.

- ✓ The environmental-friendly insulating material should have mechanical flexibility, high temperature integrity, excellent insulating properties and low cost.
- ✓ Particular attention should be paid to the mechanical and electrical properties of materials at extreme temperatures to overcome the challenges of low temperature brittleness and stark decrease in electrical properties at high temperatures.

5. Define thermosetting electrical insulation materials.

- ✓ Thermosetting electrical insulation materials include thermosetting resins and their composite materials, According to different chemical structures, they are divided into cross-linked polyolefin, phenolic resins, Epoxy resin, polyurethane and silicone, etc.
- ✓ Thermosetting electrical insulation materials are composed of covalent Bonded to form a three-dimensional network structure, it is heat-resistant and Solvent, arc resistance, tracking resistance, dimensional stability and mechanical properties, etc. are significantly improved.

6. What are the advantages of thermosetting electrical insulating materials?

- ✓ Thermosetting electrical insulation material. Use organic catalysts instead of gold Catalysts are an important means to achieve green catalysts.
- ✓ Solvent is often as reaction medium and diluent, its greening is conducive to reducing water body pollution, reduce energy consumption and improve air quality, etc.
- ✓ Use water as a solvent It is the main development of using agents instead of organic solvents to produce thermosetting electrical insulation materials.

UNIT V

EVOLVING STANDARDS FOR GREEN INSULATION SYSTEMS

1. State evolving standards of management.

- ✓ The standards suggest the use of the previous insulation system as a reference in the qualification process of a new insulation wall.
- ✓ Many standards exist and provide procedures and test methods for estimating the lifetime of an insulating system submitted to thermal stress (Ul-746, UL 1446, IEC-60216, IS-11182, etc.).

2. Define Thermal Ageing in Front of Standards

- ✓ Thermal aging is a phenomenon which is understood and documented. About the resin, standards exist and are useful in determining the lifetime of a polymeric material used in electrical equipment.
- ✓ The UL and IEC standards give a relationship between the thermal aging of an insulation material and its lifespan.
- ✓ The standards provide any indication about the combination of constraints.

3. What do you understand from standards evolutions and experimental aspects?

- ✓ Standardized tests that are able to provide information on the status of the insulation.
- ✓ During the standard ageing test, the coils are not powered and are not submitted to mechanical stresses. Moreover, the standards suggest that any added mechanical stress or electrical stress, should not introduce any significant additional aging during the thermal aging test.
- ✓ The standards provide any indication about the combination of constraints. However, the standards do not provide any indication about the combination of constraints. Moreover, many stresses are out of the scope: mechanical stress, moisture, starting conditions, etc. Manufacturers are aware of these limits and believe that existing standards need to be improved.

4. **State the standards of the high voltage insulation system**.

- ✓ The dielectric, mechanical, and thermal properties of some biobased materials and their possible applications are introduced in following paragraphs.

- ✓ Bio-based thermoplastic polymers in polymeric insulation. PLA, which is derived from corn, sorghum, and plant roots, is a bio-based material with good electrical performance. To assess the feasibility of PLA as a dielectric insulation, the volume resistivity, relative permittivity, and dielectric loss tanδ of PLA are measured

- ✓ The volume resistivity (4.9–5.5 × 1017 Ω·cm), dielectric constant (3–3.8), and tanδ (0.02–0.022) of polylactic acid (PLA) are slightly greater than those of cross-linked polyethylene (XLPE).