International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

An Overview of Quality Testing of Insulating Materials and its Technical Considerations used for Different Parts of Generator

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Abstract: ***The insulating systems are the basic requirement and have wide range of applications in the fields of power generation, electrical, electronics, telecommunications. The higher trends in modern electrical technology have led to the usage of facilitated voltage power generation. This had led to increase usage of power consumption. The insulating material is the major contributing factor in the reliability of devices. The type and quality of insulation affects its cost, weight, size, performance and life. The electrical behavior and performance of Insulating materials depends and mainly influenced by certain parameters like its dielectric strength, insulation class, porosity or penetrability, ageing, tensile strength and shelf life. These quality parameters testing enhance the stability and withstanding capability of mainly an electrical generator. In this paper, we have recorded the testing of certain resin rich and resin poor insulating materials samples under above mentioned electrical and mechanical aspects of the materials.***

Keywords: insulation class, resin rich insulating materials, resin poor materials, tensile strength, dielectric strength, shelf life.

1. Introduction

From the beginning of manufacture of electrical machines, insulation is considered as an important in deciding the life of the equipment. With the increase in the unit size of machine, the voltage ratings also steadily increased. Higher voltages demand better and more reliable insulation systems.

In initial stages of manufacture, natural fibres like cotton, jute etc were used without any impregnation. Later impregnation with oil and natural resins enriched the quality of insulation. Development of synthetic materials, and resins helped in getting more reliable insulation systems.

During this evolution ,it was realized that mica ,a naturally occurring material ,is one of the best insulations for high voltage applications. Even today there is no substitute for mica in high voltage Insulations.

1.1 Insulation Materials and Systems-

Electrical insulating materials are defined as materials, which offer a large resistance to flow of current and for that reason they are used to keep current in its proper path i.e. , along the conductor.
In electrical machines and transformers the insulating materials applied to the conductors are required to be flexible and have high specific (dielectric) strength and ability to withstand unlimited cycles of heating and cooling.

1.2 Thermal Classification of Insulating Materials-

The insulating properties of materials change considerably with temperature .As such insulating materials are classified into different classes, depending on the maximum permissible temperature on the material.

1.3 Classes of insulating materials

Y –assigned insulating temperature (degree Celsius) is 90 degrees. Insulating materials included are cotton, paper .They are neither impregnated nor immersed in oil. Material of Y class are unsuitable for electrical machines and apparatus as they deteriorate rapidly and are extremely hygroscopic.
A-assigned temperature is 105 degrees .Materials of class Y impregnated with natural resins, cellulose esters, insulating oils etc.The list also includes laminated wool and varnished paper.
E- synthetic resin enamels cotton and paper laminates with formaldehyde bonding etc. Assigned limiting temperature is upto 120 degrees.
B- mica, glass, fibres, absetos with suitable binding substances built up mica, glass fibre and asbestos laminates. Maximum permissible temperature is 130 degrees.
F- Materials of class B with binding materials of higher thermal stability. Assigned permissible temperature is 155 degrees.
H- glass fibres and asbestos materials and built up mica with silicon resins and temperature is 180 degrees.
C- mica, ceramics, glasses quality without binders with silicon resins of higher thermal stability and
Temperature is above 180 degrees.
According to IEEE standards beyond class *H*(180 degrees),*N*(200 degree),class *R* (220 degrees),class *S* (240 degrees),class *S* (240 degrees) and class *C* (over 240 degrees).

2. Different Types of Insulation Systems

2.1 Thermoplastic Insulation System-

Thermoplastic compounds are materials that go soft when heated and harden when cooled . When heat is applied the energy will allow the bonds to separate and the material can flow (melt) and be reformed ,for example-Polyvinyl Chloride – is the most commonly used thermoplastic insulator for cables. It is cheap, durable and widely available. However, the chlorine in PVC (a halogen) causes the production of thick, toxic, black smoke when burnt and can be a health hazard in areas where low smoke and toxicity are required (e.g. confined areas such as tunnels). Normal operating temperatures are typically between 75C and 105C (depending on PVC type). Temperature limit is 160C (<300mm2) and 140C (>300mm2).Another example Polyethylene – is part of a class of polymers called polyolefins.Polyethylene has lower dielectric losses than PVC and is sensitive to moisture under voltage stress (i.e. for high voltages only).

1) Shellac mica folium wrapped system
   In the early stages mica folium with shellac binder was used to wrap the straight part of coils and flexible fabric taps with varnish on overhang portions. In this system the joint between the mica folium and the tape is the weakest part. This system is no more used for high voltage machines. It has been used extensively for coils upto 6.6kv operating voltage. The main constituent materials are cellulosic backing paper, mica splittings, shellac varnish, and industrial methylated spirit.
2) Bitumen mica folium wrapped system-
   The latter development is the use of bitumen mica film in straight part and mica tape in overheating portion. But the system did not work satisfactorialy without impregnation. It has been used for insulation upto 11kv operating voltages.The constituents are same except that bitumen varnish is used.
3) Bitumen mica taped and pressure impregnation system
   As refinement of the process ,vacuum –pressure impregnation of the coils in bitumen was introduced .The system consists of taping the coils with bitumen mica tape with backing and compounding ,the insulation three-four stages with bitumen. The final coils gave satisfactory performance. It was very popular among prior to the introduction of thermosetting system. Till recently this system was in practice in some major industries.

These materials have several advantages like cheap, durable and widely available and had has lowest dielectric losses and initial dielectric strength. But these materials have certain limitations for high temperature operations as they become plastic under application of heat. Machines after regular usage for a while developed winding faults due to cracking of insulation caused by the movement of tapes. When the machine is heated up, the main insulation is swelled up and voids are created inside the insulation which result in electrical discharges and in turn damaged the main insulation. These materials also defects like highest dielectric losses and it contains halogens, its not suitable for MV / HV cables. They Highly sensitive to water treeing and Material breaks down at high temperatures.

Thermo setting insulation system-Thermosetting compounds are polymer resins that are irreversibly cured (e.g. by heat in the vulcanization process) to form a plastic or rubber. Example-

a) *Cross-Linked Polyethylene*– has different polyethylene chains linked together (“cross-linking”) which helps prevent the polymer from melting or separating at elevated temperatures. Therefore XLPE is useful for higher temperature applications. XLPE has higher dielectric losses than PE, but has better ageing characteristics and resistance to water treeing. Normal operating temperatures are typically between 90C and 110C. Temperature limit is 250C.
b) *Ethylene Propylene Rubber*– is a copolymer of ethylene and propylene, and commonly called an “elastomer”. EPR is more flexible than PE and XLPE, but has higher dielectric losses than both. Normal operating temperatures are typically between 90C and 110C. Temperature limit is 250C.

1)Resin rich system-
The introduction of epoxy resins in the field of insulation changed the systems drastically. Epoxy resin is two component reactive system. In the unactivated state(A stage) the resin remains in liquid/solid form and is not good insulating material. When the hardner /accelerator is added to the resin the system changes to B stage or semi cured stage. In this stage the resin is in transition from uncured to cured. This time needed for changing from uncured to cured stage depends on the temperature ,usually known as shelf life of the B stage resin. In the fully cured stage (C- stage) the epoxy resins have good insulating and bonding properties. The resin rich mica paper tape consists of epoxy resin in B stage as bonding material mica paper and glass backing for good tensile strength.

When heated and pressed the resin in the tape melts and hardens to form homogenus mass. As the resin in the tape is more than sufficient for providing homogenus mass, the system is known as resin rich system. Some of the materials used are-
a)semicatherm tape
b)semica flex tape

2)Resin poor system-
In the resin poor or vacuum impregnation process system, the tape contains about,8% resin and excessive accelelerator/ hardner. After taping, the coil is impregnated in an epoxy resin having no accelerator. As the tape contains the accelerator, the resin reacts with accelerator and forms a homogenus mass when heated and pressed. In this system the impregnation is done under pressure after removing all gases by creating vacuum .As such insulation will be void free and more compact. The tape used may be either mica paper or mica flake tape. The materials used for 2 pole generators and 4 pole generators.

1) Bar impregnation
2) Form impregnation
3) Total impregnation.

Some widely used insulating materials for in different parts above generators are
a) resin poor mica tape
b) nomex glass fleece

3. Testing of Insulating Materials-

The resin poor insulating materials are comparatively advantageous than resin rich insulating materials.The samples insulating materials are being tested through various tests evaluating various important insulating properties of the insulating materials. The samples are tested mainly on the following parameters-

1) Insulation class
2) Tensile strength
3) Dielectric strength
4) Shelf life
5) Total weight age
6) Porosity or penetrability

- *Testing of tensile strength*-the minimum tensile load per unit of the the orginal cross section of body which will cause its rupture under specified conditions of test,expressed in pounds per square inch or kilograms per square millimeters.

- *Testing of dielectric strength*-the value of voltage which causes the electrical rapture of an insulating material in practical use. The value obtained must be qualified by reference to the type of voltage applied,the method of its application ,the uniformity of the electrical field developed,the thickness of the insulation tested,the temperature and the conditioning treatment to which the material has been exposed before and during the actual test.

- *Dielectric constant* –the ratio of capacitance of a material measured with a given electrode configuration to the capacitance of same electrode configuration and spacing with air as a dielectric.

- *Dielectric loss*-when an ac voltage is applied to an electrical insulating material, heat is generated because of its imperfect dielectric nature.The time rate at which the electrical energy is transformed into heat is designated as the dielectric loss and is expressed as watts/cubic centimeter.

- *Test of ageing*-the change which is observed in one or more properties of material during its normal commercial use.

- *Test of porosity or penetrability*-the testing of penetrability is done on a sample of the insulating tape material and checked that there is no dry patch/layer of the tape.

- *Shelf life*-the ability of material to maintain its usability during storage ,expressed in terms of time under prescribed conditions of temperature,light oxidation and humidity.

4. Results and Discussions

4.1 Semicatherm Tape-

Semicatherm tape is a resin rich mica paper tape with glass backing. The tape contains mica paper, epoxy resin in B stage and glass cloth backing. semicatherm tape is used for main insulation of stator bars. Its insulation class is class F i.e its permissible temperature is 155 degrees. The tensile strength of semicatherm tape or resin rich tape is 15kg/cm width. Dielectric strength is 35 kv/mm. Shelf life evaluated at two different temperature levels-6 months at 20 degrees and 12 months at 5 degrees.

4.2 Semica Flex Tape-

It contains mica paper with glass backing bonded by selicon resin.The insulation remains flexible even after curing. Its main application is for flexible insulation on over hangs of diamond coils.

- Tensile strength is 12kg/cm width
- Dielectric strength is 20kv/mm.
- Shelf life is 4 months at 20 degrees and 8 months at 5 degrees.

4.3 Resin Poor Mica Tape-

Resin poor mica tape is used for main insulation. The tensile strength of the tape is 8N/mm of the tape.
Dielectric strength is 2.3kv.
Total weight age is 7,8 gm/mm .
Porosity or penetrability is 45.
Shelf life is 6 months at 20 degrees and 12 months at 5 degrees.

Nomex glass fleece-
It is used as transposition pieces.
Dielectric strength is min 5kv/mm
Shelf life is 6 months at 20 degrees and 12 months at 5 degrees.

5. Conclusion

The above mentioned insulation systems are being practiced at BHEL Hyderabad and the insulating materials used for main insulation and other parts of a generator have qualified the thermal cycling and electrical tests as per the the design and operational requirements. These insulating materials have proven to be suitable for operation in high electromagnetic stress environments. These Insulating systems and its materials meet the increasing demands of quality and quantity. Quality Demands for all electrical and electronic parts for automotive industries and high voltage applications Parts have driven upwards to values to the values that approach traditional insulation break down levels. The technical solutions described above have demonstrated these capabilities It shows cost effective increase in quality of the protection of the generators.

6. Acknowledgement

Authors would like to thank the management of Bharat Heavy Electricals Limited Hyderabad for giving permission to publish this paper. Both the professor and management of BHEL have encouraged and extended their unstinted support and guidance.

References

[1] Karl Farooq, IEEE Int symp on electrical insulation,PP1619,Montreal,Quebec,Canada,june 1996.
[2] Y.Yamano,Y Takahashi and S.Kobayashi,IEEE Trans.On Electrical Insulation,VOL-25,No.6,PP1174-1179,1990.
[3] A.Beroual and A.Boubakeur,IEEE Trans. On Electrical Insulation,Vol-EI-26,PP1130-1139,1991.
[4] M.A.R.M.Fernando,S.M.Gub-anski,"leakage currents on non-ceramic insulating and materials" IEEE trans on dielectric and elect insul,vol 6.No.5,pp660-667,oct.1999.
[5] Clark ,F.M., "Insulating material for design and engineering practice" Wiley ,1962.
[6] Ekram Hussain,M.M.Mohsin and S.R.S.Naqvi "Insulating materials for super conductors and their characteristic at cryogenic temperature" 1998 IEEE international conference on conduction and breakdown in solid dielectronics June 22-25.1998.Vasteras,Sweden.
[7] Prabhu G.S and Sarda L.M.,"criteria for selection of impregnating Resin for VPI insulation system",presented at INSULEC-88,Mumbai 1988.
[8] Thomas kainmuller, Roland Moser and Robert Kultzow, "Single Component Epoxy systems used for enhanced electrical performance and applications".presented at coil winding.Cincinnati,1999.